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The codability and retention characteristics of movement direction and distance cues in the horizontal plane.

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THE CODABILITY AND RETENTION CHARACTERISTICS

OF MOVEMENT DIRECTION AND DISTANCE

CUES IN THE HORIZONTAL PLANE

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ABSTRACT

The retention characteristics of direction, distance, active and passive movement cues were examined over independent variables of Movement Set, Retention Interval, and Angle of Movement. The task involved reproducing movement direction and distance, the Ss being 80 male high school student volunteers. The results were analyzed by a 2 X 4 X 3 factorial design with repeated measures on the last factor and discussed in terms of the processes that occur in KSTM. The error detection process was indexed by $\overline{CE}$, the error detection criterion level, and VE, the sensitivity of the detection mechanism. $\overline{AE}$ was considered an index of the accuracy of the memory trace and AV was a measure of the strength of the memory trace.

It was demonstrated that direction and active movement cues were used to formulate a more accurate error detection level and sensitive detection mechanism than distance and passive movement cues. With respect to the memory trace process, direction and active movement cues were more exactly and precisely represented in memory than distance and passive movement cues. In essence, information from distance and passive cues was capable of being used for movement reproduction, but not to the same extent as

information from direction and active cues. A model of KSTM was proposed which incorporates the error detection and memory trace processes.

This research also indicated that timing was not employed by S as a cue upon which movement reproductions are based. S concentrated on cues inherent in the movement when making a reproduction rather than formulating cues based on extrinsic factors such as counting.

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CHAPTER I

INTRODUCTION

Kinesthetic Short-Term Memory

A primary function of secondary school physical educators is the instruction of movement skills, and inherent in skill acquisition is memory. Memory can be considered the learned capacity for recalling something and in skill acquisition it entails the reproduction of a movement. Research in physical education, particularly in the area of motor learning, has been concerned with methods of instruction and techniques of skill learning including the transfer of skill, reinforcement, practice distribution, and mental practice. Only within the last ten years have researchers in the area of physical education contributed to the investigations of psychologists on movement reproduction. Movement cues utilized in the reproduction of a movement such as extent, location, and torque are now being examined. Another cue that may be used in the reproduction of a movement is direction which in combination with movement extent cues is the concern of this study.

Before an examination of the literature on movement cues will be undertaken, which forms the foundation for the present study, the results of experiments conducted in the areas of movement execution and memory, applicable to the present study, will be reviewed. Woodworth (1898) did much of the original research on movement execution with vision eliminated. He reported speed of movement had little influence on movement accuracy, however faster speeds resulted in movements longer than a criterion movement (CM) and slower speeds resulted in shorter movements. He also found evidence to support what more recent investigators have termed the range effect; small distances are regularly exaggerated and longer movements are regularly made too short.

Research dealing with movements made in various directions was undertaken by Brodgen et al. (1949) using a tracking task. It was found that movements separated by 180° were equal in accuracy with right-handed movements of 45° being most accurate and movements of 135° being least accurate (0° - 180° being in the horizontal plane running parallel to the shoulders). Begbie (1959) reported results similar to those of Brodgen(1949) and also noted that left-handed movements obeyed the same relationships except were inverted with respect to right-handed movements. In addition, it was shown that short movements were drawn in a relatively straight line with vision eliminated.

The relationship between the direction and the velocity of movement in the horizontal plane has been investigated by Schmidtke & Stier (1961). The results showed the same mathematical interrelationship for all subjects. Starting from 0° (the 0°– 180° axis being similar to that employed by Brodgen, 1949) the motion time decreased to a minimum at approximately 45°, and from there lengthened to a maximum near 135°.

The accuracy of movement and motion time as a function of movement direction possibly results from movement to two different joints: (1) movement of the forearm about the elbow and (2) movement about the shoulder joint. Moving on the 45° axis involves primarily movement of the forearm about the elbow whereas the 135° axis involves mainly movement at the shoulder joint (Schmidtke & Stier, 1961). The accuracy of movement can be accounted for in terms of arm steadiness. As a subject moves along the 45° axis, the relatively large unsteadiness at the elbow will result in fluctuations parallel to the direction of travel. For movement along the 135° axis, unsteadiness at the elbow will be perpendicular to the line of travel. Accordingly, as the direction of movement is changed from 45° to 135°, there will be a decrease in movement accuracy (Begbie,1959).

As with movement execution, memory was investigated by psychologists in the late nineteenth century. James (1890) outlined what was termed " matters of popular knowledge "; material is better remembered if it was recently presented, rehearsed, and meaningful. Prior to 1960, memory studies concentrated on long term memory, the learned capacity for recalling something over a retention interval ranging from hours to months or years. Researchers found memory was influenced by factors including the amount of original learned material, the retention interval length, and the degree of task complexity. In addition, memory was also effected by the method of measurement. Since 1960 investigators have become interested in the area of short-term memory (STM), which can be designated as the memory of events that have just been presented (Stelmach, 1974). The capacity of this storage system is believed to be limited with respect to the number of items stored and recall or recognition is usually a matter of seconds.

Determining the cause of forgetting has been the basic approach for studying the nature of STM. Two primary theories explaining the cause of forgetting have been postulated, trace decay theory which states that stored information spontaneously decays over time and that forgetting is the result of a weakened memory trace at the time of recall. Interference theory proposes that forgetting is a result of competing responses learned before or after the criterion item which somehow disrupt the memory trace. A combination of these two theories, termed the acid bath theory, suggests that interfering items interact with the stored trace spontaneously during the retention interval to weaken its strength. This theory predicts that the memory trace is altered as a function of time, as well as number and similarity of items in storage.

STM researchers investigating verbal response classes have found some support for trace decay (Brown, 1958), but most research and the largest volume of evidence has concerned interference theory. Thefe are two types of interference; proactive interference (PI) results from competing responses presented prior to the criterion response and retroactive interference (RI) results from competing responses presented following the criterion response. PI has been demonstrated to negatively influence ~~recall~~ with one and two prior presented items, and experimenters have concluded that PI increases as the number of interfering items and the degree of learning of prior items increases (Peterson & Peterson, 1959; Wickelgren, 1966a;Keppel & Underwood, 1962). RI studies have also shown forgetting as the number of items interpolated between the criterion and the recall responses is increased (Conrad, 1964). Wickelgren (1965b) has further demonstrated that RI increases as the acoustic similarity between the criterion item and the interpolated items increases.

The research on STM concerned with verbal response classes led directly to studies involving motor responses. Accordingly, motor short-term memory (MSTM) studies have been concerned with an examination of the roles of trace decay and interference in movement recall to determine if they have the same characteristics. The following section will review the experimental findings of MSTM* research in some depth, since the work on movement cues has been an extension of that conducted on simple movement reproduction.

Trace Decay and Interference

MSTM Studies

Only marginal support has been found for trace decay as an explanation of forgetting in MSTM. Stelmach (1969) reported considerable forgetting in the no-prior-response condition as a function of the length of the retention interval. Comparisons of immediate recall to 20 seconds of rest in a study by Stelmach & Wilson (1970) indicated increased forgetting over time. Furthermore, Adams, Marshall & Goetz (1972) found validity for the theory of trace decay as retention was found to decrease over time in the rest conditions. Finally, Roy & Davenport (1972) concluded that some credence should be given to trace decay when they found a decrease in recall accuracy as a function of time given interpolated activity is held constant and time varied. Consequently, while the evidence has been derived from interference experiments rather than from experiments

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* KSTM (kinesthetic short-term memory) may be substituted for MSTM in this thesis when only kinesthetic information is used for movement recall.

examining trace decay, it seems to be adequate support for a trace decay interpretation of forgetting.

Interference experiments, as discussed previously, are divided into two types, PI and RI.

Proactive paradigms:Tasks employing proactive paradigms have investigated variables including the number of prior trials presented, the length of the inter-trial interval (ITI), the number of prior items presented within a trial, and the similarity of prior items to the criterion item. Adams & Dijkstra (1966) the original research in MSTM, failed to find the number of trials to be a relevant cause of forgetting. The length of the inter-trial interval was investigated by Montague & Hillix (1968) because they felt that kinesthetic traces may decay too rapidly to produce PI if the ITI was extensive. Utilizing an ITI as short as 10 seconds, no indication that the length of the ITI influenced PI was demonstrated. Schmidt & Ascoli (1970) varying the length of the ITI between 10 and 90 seconds reported similar results and concluded that PI does not accumulate over trials.

Proactive paradigms have shown that interference is a factor within a given trial. Ascoli & Schmidt (1966) presented findings showing that PI was produced if four items preceded the criterion item. Stelmach (1969) and Craft & Henrichs (1971) also found prior items decreased recall accuracy, these results being achieved with two and three prior items, respectively. Williams (1970) also demonstrated forgetting to be due to PI, however, five trials was required to produce the decreased accuracy. It is clear that the number of preceding items within a given trial negatively influences the recall of the criterion item, but the minimum number of prior items required to produce PI has been found to vary between two and five depending on the experiment.

Evidence reported by Stelmach (1969) seemed to indicate that short-term retention of a simple motor response was inversely related to the similarity of prior responses about a target. Craft & Henrichs (1971) also observed directional error trends as a function of the similarity between motor responses. In contrast, Salmoni (1971) found increased similarity caused an increase in recall error for distance and a decrease in recall for speed. He argued that previous researchers confounded similarity with reinforcements and error tolerance.

Retroactive paradigms: Task variables employed in examining RI have included the number of interpolated movements, the relative size of the interpolated movements, the length of time an interpolated location is held, the difficulty of the interpolated activity and the rehearsal of the CM. The type of activity interpolated between the CM and the reproduction movement (RM) has been comprised of movements identical to the CM, movements similar to the CM, gross body movements, mental activity, and minimum activity (rest).

Several studies have demonstrated that RI resulting from interpolated movements similar to the CM is a primary source of forgetting in MSTM (Montgomery, 1970; Roy, 1972). It was concluded by Roy & Davenport (1972) after varying the number of interpolated movements within a retention interval that at least four interference responses are required before recall decrements are observed. The relative magnitude of an interpolated movement has also been shown to produce a shift in the direction of the recall response (increased forgetting). This response biasing was in the direction of and proportional to the extent of the interpolated movement (Pepper & Herman, 1970).

In a study to investigate if time at an interpolated location would increase response biasing, Stelmach & Walsh (1972) reported that the longer the interpolated location was held, the greater the directional shift towards that point. In other experiments utilizing linear slide tasks (Craft & Henricks, 1971; Patrick, 1971), directional response biasing has also been evidenced. Trumbo et al. (1972) demonstrated increasing the number of interpolated movements had the effect of increasing the directional shift. This biasing was hypothesized to result from the criterion trace decaying and becoming more susceptible to interference from an interpolated memory trace.

Posner (1967) reported that retention in verbal STM is an active process which requires a portion of the information processing capacity of the brain. If a difficult information processing task is interpolated between the criterion and recall tasks, forgetting occurs proportional to the degree of difficulty. Stelmach (1970) and Kantowitz (1972) found no evidence that difficulty of information processing of an interpolated task is a major factor in the accuracy of motor recall. Some studies have produced support for the concept that information processing activity influences recall accuracy. Stelmach & Wilson (1970) reported recall of short movements is somewhat dependent on the available processing capacity during the retention interval; recall of long movements is not. Marteniuk (1973) has shown spatial-location information received from the kinesthetic modality requires some central processing if it is to be retained.

The rehearsal of kinesthetic cues was first examined by Adams & Dijkstra (1966) who showed that repetition of a positioning movement prior to recall decreased forgetting. This finding agreed with results reported in verbal behavior (Peterson & Peterson, 1959), but other MSTM research has failed to demonstrate similar results. Pepper & Herman (1970) found larger recall errors associated with the greater number of repetitions of the CM. Generally, most MSTM studies have found that the best form of rehearsal is remaining at the end-point of a movement. Stelmach & McClure (1973) showed longer retention intervals of 24 and 56 seconds holding a target location gave the greatest recall accuracy.

The majority of MSTM studies have dealt with the influence of interfering activities. The evidence definately indicates that certain movements presented in specific ways are important variables in effecting the accuracy of recall of criterion motor acts. Although some of the results from MSTM experiments are conflicting, MSTM investigators have achieved significant insight into the nature of this memory system; much work still must be undertaken, nevertheless, before a satisfactory understanding of MSTM is reached. The final point that can be drawn from examining MSTM research is that interference is definately supported as a theory of forgetting in motor memory, and seems to be a more viable approach than trace decay to the study of this memory system.

The studies discussed above provided the foundation for the studies on movement cues. The research that has dealt with movement cues to date has focused primarily on movement location and movement distance. The findings for the retention characteristics of movement distance cues have been conflicting, and the present study will, therefore, further examine distance cues. In addition, this thesis will extend the knowledge on movement cue reproduction by investigating the retention characteristics of movement direction cues and active and passive movement cues.

Definition of Terms

Active Movement A movement made by S containing an efferent copy of the motor program for the movement and active feedback from the kinesthetic system.
Criterion Movement The original movement made by the S or presented to S by the experimenter (E). It was started at a fixed point and extended approximately four inches in one of three directions.
Direction The movement extending from a given point through space measured in degrees from the horizontal. The movements extended from the midpoint of the baseline of a half circle between 0° and 180°.
Distance (Extent) The extent of a movement from a given point in cms.
Encoding The process of representing one signal by another. It was difficult to determine the nature of the representation, but one way of assessing this was to analyze errors in recall. Encoding was measured through movement reproduction accuracy, direction in degrees and extent in cms.
Error The deviation between the observed movement and the

CM measured in degrees and cms.

Absolute error (AE): unsigned error.

Average variation (AV): the standard deviation of the $\overline{AE}$.

Constant error (CE): algebraic error or signed error.

Variable error (VE): the standard deviation of the $\overline{CE}$.[1]

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[1] Previous MSTM researchers have used $\overline{CE}$ and $\overline{VE}$ as the dependent variables in their experiments, contending that only these two statistics are necessary and sufficient to describe the distribution of error movement reproduction scores made by S. They have argued that a third statistic ($\overline{AE}$) is redundant and should not be used. This is certainly a logical arguement, as long as $\overline{CE}$ and $\overline{AE}$ are describing the same distribution of scores. It is the contention of this author that two processes must be examined in KSTM, which are represented by two separate distributions of scores.

One process in KSTM operates similar to a servo mechanism, which can be termed the error detection mechanism. A servo mechanism has an error detector which produces an error signal when there is a difference between the output, which is monitored by way of a feedback system, and the standard value to which it is being compared. Some servo mechanisms operate so that an error signal is produced only when the output deviates by a predetermined amount from the standard value. $\overline{CE}$ is a measure of the predetermined level of detection established. In the case of KSTM, S sets an error detection level, which he utilizes in monitoring the feedback from his attempt at reproducing the CM. CE is an index of this detection level, the closer $\overline{CE}$ being to zero the less the error that S is willing to tolerate when making a movement reproduction.

There is usually some interval activity within a servo mechanism and the error signal must be separated from this interval noise. The separation of the two depends upon the strength of the signal. The signal becomes weaker as the error approaches zero, which makes it very difficult to separate the error signal from the internal noise. S uses a similar technique when making a movement reproduction. S monitors the feedback with the error detection mechanisms, Information The knowledge concerning the distance and direction of a movement derived from the kinesthetic system.

Kinesthetic Cues Information generated from the self movement of the arm of the subject. The kinesthetic cues were distance and direction and were measured in units of cms. and degrees, respectively.

Location (starting-point) The point in space from which a line was extended. The starting point for the CM was fixed and the starting point for the RM coincided with the terminal point of the CM.

Location (end-point) The point in space at which a movement was terminated measured in cms. from the starting-point.

Passive Movement A movement resulting from E passively moving S containing passive feedback from the kinesthetic system, but no efferent copy of a motor program since S did not initiate the movement.

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however, it the error signal is weak S may believe a signal has occurred when it has not. VE is the index of the sensitivity of the error detection process.

The second process that must be examined in KSTM concerns the state of the memory trace. AE gives the magnitude of the error between the CM and the RM. It is an index of the accuracy of the memory trace; how accurately S can reproduce the CM employing the error detection level he has formulated. As such, AE is a measure of forgetting, the larger the AE and the greater the retention loss. AV is the variability of the movement reproduction accuracy exhibited by S. Therefore, AV, the index of the precision of the memory trace, is a measure of the strength of the memory trace. A large AV indicates a weak trace while a small AV indicates the trace is very stable.

<u>Recall</u> The reproduction of a movement previously presented measured by the difference (error) between the criterion and reproduction values.

<u>Reproduction Movement</u> The movement made by the <u>S</u> in an attempt to reproduce the CM. The RMs were based on distance and direction cues.

<u>Short-term Kinesthetic Memory</u> The memory of a movement that was stored, from information received from the kinesthetic system. It was measured by movement reproduction accuracy.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter is concerned with the experiments that are related to or have examined movement cue reproduction. Studies involving the reproduction of a simple movement, that are related to the research on movement cues, will be discussed initially. Work, investigating specific movement cue reproduction will then be reviewed, and finally the models that have been proposed to describe the retention characteristics of movement cues will be considered.

Movement Studies

The research which ignited the interest in kinesthetic short-term memory and set an example for following studies was conducted by Adams & Dijkstra (1966). Accordingly, this study will be examined in some detail. Their study, consisting of two experiments, was conducted to determine if the empirical laws emerging for verbal behaviour would hold for other response classes. Specifically, the two experiments were designed to determine if the short term retention of simple motor responses obeyed two prominant generalizations for the forgetting of verbal responses in STM: (a) accuracy of recall decreases rapidly as a function of time, and

(b) accuracy of recall is positively related to the number of practice repetitions.

In Experiment I a simple linear motor response was performed on a linear slide. To insure that S's responding was based on motor and not on a combination of motor and visual cues, vision was eliminated by a curtain. The criterion movement, retention interval and recall of a response constituted a single trial. The distance through which the S had to move a lever on the slide was determined by E with the positioning of slide stoppers. At the instruction "move" S moved his slide from the starting position on the right to a fixed stop. S then returned his slide to the starting position on the E's instruction "return" after holding the end position for 3 seconds. This sequence of events defined the correct response for S and was the definition of a CM in the task. Repetition of the CM occured at 3 second intervals if S was in a multiple reinforcement condition.

When S returned the slide to the starting position after the final repetition, his hand remained on the slide throughout a retention interval. During the retention interval the stop screw was removed from the slide so that S's recall could be unrestricted and free to take any value. At the end of the retention interval E said to "estimate" and then S recalled the length of movement that was practiced in the repetition sequence. Error was measured in millimeters being either negative or positive in sign. Instructions deemphasized speed and stressed that movements should be deliberate and accurate. ITIs of 3 minutes were used to control the interference that could possibly build up between trials if shorter intervals were employed.

The experimental design included response lengths of 32,24, and 8 cm. paired with retention intervals of 7,10, and 30 seconds respectively, with the same number of reinforcements for a particular S that would be administered to him in the subsequent criterion trials. Each S was then given seven criterion trials, and a response of a different length was reinforced and recalled on each trial. Furthermore, each response length had associated with it one of seven retention intervals so each of the seven different response lengths on the seven trials had a different retention interval assigned to it. The seven response lengths were 10,14,18,22,30 and 34 cm; and the seven retention intervals were 5,10,15,20,50,80, and 120 seconds. Each S received the same number of repetitions for all his responses, which was either 1,3, or 6 depending upon the experimental condition.

The results were analyzed in terms of AE, and it was found that there were trends of increasing error with increases in length of the retention interval and decreasing error as number of repetitions increased, which was interpreted as being consistent with findings for verbal studies.

However, the number of repetitions failed to be statistically significant.

To re-examine the concept that accuracy of recall is positively related to number of practice repetitions, Adams & Dijkstra (1966) conducted a second experiment. The design was the same as Experiment 1 except the three reinforcement conditions were changed to 1,6, and 15. It was concluded accuracy of short-term motor recall is a decreasing function of time measured in seconds and is a positive function of number of repetitions when the range is significantly large. The findings were considered consistent with the hypothesis of a decaying trace that becomes increasingly stable with reinforcement.

Following the work of Adams & Dijkstra (1966), the bulk of short-term motor memory studies used some form of induced motor activity in an attempt to alter or increase the forgetting process. The findings from these experiments were outlined in Chapter I. The other experiment that should be considered in detail, that dealt with the retention of movements per se, was conducted by Pepper & Herman (1970). From this study the authors developed a model of MSTM that has received considerable attention by other researchers. The study examined the short-term retention of applied force as a function of a variety of independent variables. These included (a) the length of the retention interval, (b) rehearsal opportunity during the retention interval, (c) the application of various magnitudes of interpolated forces applied in either the same or opposite direction to the criterion force, and (d) the number of repetitions of the force response occuring prior to the retention interval.

The task was to apply a force of a given magnitude and direction by either pushing or pulling vertically on a knob attached to a special force transducer. The criterion force was applied while S observed a visual analog of the produced force. During the recall trial, S was required to reproduce the same force without visual guidance. The force transducer provided a potential force range of 0-4.5 Kg. in response to either an upward or downward applied force. The required force response was signaled to S through a two-element numeric display which indicated the magnitude and direction of the force to apply.

The general procedure used by Pepper & Herman (1970) involved the S sitting in a sound insulated chamber. The S gripped the control knob with his right hand and produced the criterion force as shown on the digit display and received visual feedback (oscilloscope). Offset of the display was the signal for S to relax his applied force and allow the visual trace to return to a central position. During recall trials, S was required to apply what he felt to be the correct force based on the preceding experience of applying that particular force under visual feedback.

In Experiment 1, the effect of retention interval length on recall of an applied criterion force was investigated. The retention intervals were always unfilled, S merely sitting passively until required to recall the criterion force. The S's were 8 male and 12 female undergraduate university students. A 5 X 2 X 5 repeated measures design was used to test for effects of force level, direction of movement and length of retention interval, respectively. The force levels were .85 Kg and increases up or down of 1.70, 2.55, 3.40, and 4.25 Kg. The retention intervals used were 4,8,12,30, and 60 seconds.

The experiment failed to demonstrate a significant decrement in recall over retention intervals up to 60 seconds. This finding was in opposition to previous research (Adams & Dijkstra, 1966; Posner, 1967) which reported significant decrements in their kinesthetic-distance tasks with time intervals as short as 10 seconds. In accord with the concept of spontaneous trace decay, Williams et al.(1969) and Posner & Konick (1966b) found that rehearsal opportunity played only a minor role in MSTM. In Experiment II Pepper & Herman (1970) added the variable of interpolated activity to further examine the concept of rehearsal.

The procedures were identical to the first experiment except for the inclusion of an interpolated counting task on half of the trials. For this task, following application of the criterion force, S heard a three-digit number over an intercom system and simultaneously heard a tone pulsing once per second. These were the signals for S to (a) repeat the heard number and (b) begin counting backwards from that number by threes in time with the pacing tone.

The evidence from this experiment indicated the tendency of Ss to overshoot the criterion force during the recall trial. At all retention intervals, filled trials were associated with larger errors, for both absolute and algebraic scores, than were unfilled trials. Overall, decreasing recall errors of both types occured as the retention interval lengthened. The Es felt this finding could not be handled by the simple concept of the preclusion of rehearsal opportunity, since this concept requires that forgetting increases over time for filled but not for unfilled intervals.

To account for these results, Pepper & Herman (1970) formed the following assumptions: (a) an accurate memory trace of the intensity or extent of the criterion motor act is initially stored, but is subject to decay over time; (b) the decay occurs on the dimension of represented intensity or extent of the original act; and (c) the response set of S remains constant over the retention interval. During recall, S makes his response by attempting to reproduce the momentary represented intensity of the decaying trace. Algebraic error is seen to move always in the negative direction over the retention interval since the trace signifies an increasingly weaker force or lesser movement extent as time increases. If the response set is one of overshooting, then over time increasingly accurate scores may be obtained with respect to the original criterion act since he begins to approach the initial representation rather than depart from it.

Pepper & Herman (1970) further postulated that interpolated activity may act to alter the memory trace. The trace of a motor item may be augmented by an interpolated activity that is essentially unrelated to the item and primarily non-motor in its characteristics through an increase in the level of general muscle tension.

To test their concept of interpolated activity, Pepper & Herman (1970) conducted a third experiment in which the recall of a criterion force was measured as a function of application of a second force during the retention interval. Characteristics of the interpolated force were varied along two dimensions: (a) force magnitude as compared with the criterion force, and (b) force direction with respect to the criterion force. Comparisons were made with recall performance observed when the interpolated activity was counting backwards and when it was merely sitting quietly. The general procedure used was similar to that of the previous experiments.

It was found the relative-direction effect was small, with no consistant trend evident. Greater forces produced larger errors then lesser forces. Comparison of counting and sitting tasks showed consistently larger errors associated with counting. Greater forces and the counting task yeilded roughly comparable mean errors, as did lesser forces and the sitting task.

The researchers felt that these findings supported the concept of increased muscle activity arising from such activities as counting backwards, which interact with the criterion trace to produce a more intense trace, yeilding a recall measure which is considerably larger than that for a resting condition. They assumed this to be an assimilation process in that the recall response moves in the direction of the level of the increased residual stimulation arising from the interpolated task. The trace which represents the combination of the criterion act and the interpolated task at recall was conceived to represent the mean intensity of the two.

Experiment IV investigated the possibility of rehearsal of a criterion force by successive repetitions to determine if this variable could be incorporated within the assumptions previously outlined. It was found that larger recall errors were associated with the greater number of repetitions. It was suggested by Pepper & Herman (1970) that the criterion trace was augmented by the

the repetitions in accord with the increase in muscle tension.

Distance and Location Cue Studies

Recently, MSTM researchers have approached the investigation of movement reproduction in a different manner. Rather than examining the reproduction of movement per se, endevours to isolate different cues upon which movement reproduction is based and investigate the retention characteristics has been the focal point. The establishment of what is encoded into the memory system and how this information is stored before it can be decided what is maintained, is the primary arguement for this type of research. Laabs (1973) conducted two experiments to investigate the possibility that kinesthetic location information has characteristics that are different from those of kinesthetic distance information. CE and VE were used as the dependent variables since Laabs felt these two are the determiners of AE, and inaccurate interpretation of experimental data can result from using AE as a dependent variable (Schutz & Roy, 1973).

Experiment I used VE to test the hypothesis that an unfilled retention interval results in a decrease in reproduction accuracy of movement distance but had little effect on the reproduction of movement location. The assumptions of the assimilation theory of MSTM (Pepper & Herman, 1970) that all kinesthetic-proprioceptive information spontaneously decays and that decay is indexed by CE were also evaluated. Forty-five right-handed <u>S</u>s from the University of Oregon were employed in the study. The apparatus consisted of a bar which swung freely about a pivot located under the apex of a pie-shaped box. <u>S</u>s sat in a swivel chair in front of the apparatus and grasped the movement bar. On the command "move", the <u>S</u> slid his arm to the right until encountering a stop made from a large paper clip. The <u>S</u> held the bar at the stop for 3 seconds and then released on <u>E</u>'s command. Then the <u>S</u> removed his head and arm from the box and swung his chair to the left. The <u>E</u> repositioned the bar and either immediately or after a 12 second rest asked the <u>S</u> to recall the CM. <u>S</u> then regrasped the bar and made his RM.

The <u>S</u>s were assigned randomly to one of two groups. Group D reproduced movement distance and all RMs started at points different from their CMs to make final location an irrelevant cue. Group L reproduced movement end-location and all reproduced movements started at points different from their CMs to make distance an irrelevant cue. In order to compare the groups, the RMs of each were matched in length and final location. There were six movement lengths ranging from 10° to 35° in 5° steps. There were 12 final locations which were separated by 5° intervals and divided into three 20^{o} sectors.

The data from this experiment supported the hypothesis that while distance information decays over a retention interval, location information decays very little. CE indicated that smaller movements tended to be overshot and large movements undershot, however, this trend was much greater for Group L than Group D. This suggested to Laabs (1973) that there was a range effect for movement location similar to that usually observed for movement length. The delay effect was also significant. However, with increased delay the CE-shift was from less positive to more positive or in the positive direction for Group L. A CE-shift in a negative direction, which was predicted by Pepper & Herman (1970), was only demonstrated by Group D and only with the relatively large movements. Thus support was provided for the decaying trace assumptions of the work of Pepper & Herman (1970) only when the S reproduced movement distance and only when he reproduced the relatively larger movements.

The purpose of Experiment II was to investigate the effect of interpolated mental activity on the retention of location information. VE was used in testing the hypothesis that mental activity performed during a retention interval results in a decrease in reproduction accuracy of movement location but has little added effect on the reproduction accuracy of movement distance over that observed for an unfilled retention interval. Also evaluated were the assumptions of the work of Pepper & Herman (1970) that a kinesthetic memory trace is augmented by an increased level of proprioceptive stimulation resulting from interpolated activity and that this assimilation effect is indexed by a CE-shift in the positive direction when filled and unfilled retention intervals are compared.

The general procedure followed was similar to the first experiment with the addition of two delay conditions containing interpolated mental activity. One interpolated task was counting backwards by three and the second was a spatial reasoning task in which Ss were required to compare three-dimensional figures with a fold out pattern and decide whether each figure could be made from the pattern. As with the delay with rest conditions, the delay with counting and the delay with spatial reasoning conditions were 12 seconds in duration.

The VE analysis showed a large increase in variability after a 12 second rest over that for immediate reproduction of location replicating the findings of Experiment I. When interpolated activity was added there was a large increase in variability over that for immediate reproduction of location but no orderly change in variability over that for immediate reproduction of distance. The counting and spatial reasoning conditions did not significantly differ. The only significant effect in an ANOVA of the forgetting scores was the Task X Delay Interaction. Further analyses showed that the simple main effect for location reproduction was significant while the simple main effect for distance reproduction was not, which supported the hypothesis that remembering location information is subject to interference from activity which blocks rehearsal, but that remembering distance information is not much effected beyond the forgetting that occurs during an empty interval. The analyses of CE yielded little support for the assimilation theory of MSTM. A comparison of immediate reproduction and 12 seconds rest demonstrated a CE-shift, as assumed in the assimilation model, only for the larger movements in distance reproduction. The predicted positive CE-shift or a decrease in undershooting when 12 seconds rest was compared to spatial reasoning was not found. An increase in undershooting was actually found.

To Laabs the data indicated separate memory functions for kinesthetic location information and kinesthetic distance information when used as cues in movement reproduction. He concluded that distance information appears to spontaneously decay while location information seems to be rehearsable in some manner as long as processing capacity is available.

Marteniuk & Roy (1972b) also examined the retention characteristics of distance and location cues. The study was designed to investigate the two variables under immediate reproduction, reproduction after 10 seconds of mental rehearsal, and reproduction after 10 seconds of an interpolated distracting task (successive doubling of an odd digit number). The other variables of interest were feedback, active and passive. Active feedback contained efferent information and was produced from active movement. Passive feedback contained no efferent information and was produced as the result of passive presentation of the CM. The experimental procedure involved an angular movement similar to that utilized by Laabs (1973).

The data of the experiment showed that active movement produced less absolute reproduction error than passive movement. The mean AE of these two conditions was 7.03° for the active condition and 9.34° for the passive condition, which was statistically significant. The fact that the smaller error was associated with active movement seemed to indicate that motor outflow might be a source of information upon which movement reproductions are based.

The data also demonstrated that the use of location cues resulted in more accurate performance than conditions that rely only on distance cues. This finding confirmed the evidence produced in a previous study of Marteniuk and Roy (1972a).

With respect to the interpolated conditions used during the retention interval, it was found that overall, rehearsal tended to maintain the strength of the memory trace to a state at least comparable to that of immediately after presentation of the standard movement. On the other hand, the memory trace was altered from its original form by interpolated mental activity.

The main interest of the study centered on the interaction of distance and location cues with the three different retention intervals and the interaction of type of feedback with the retention intervals. The researchers hypothesized that location cues could be rehearsed and therefore the memory trace should show minimal forgetting over time. Interpolated activity, in contrast, because it would block rehearsal, would inhibit rehearsal and forgetting would take place during the retention interval. It was further hypothesized that distance cues were not codable and accordingly performance would not be influenced by either rehearsal or interpolated mental activity. A similar hypothesis was formulated by the experimenters for active versus passive movement. They postulated that active movement contained more codable feedback than passive movement, and therefore rehearsal would facilitate performance for an active movement to a greater degree than for a passive movement.

The data showed that both the interactions that were of special interest were non-significant and the hypotheses were not supported. The analyses of these two interactions, however, still produced some meaningful relationships.

First, there was a constant difference between active and passive movement and location and distance over the three retention intervals. Second, the trend of each of these four variables over the retention intervals illustrated that the immediate and 10 second rehearsal conditions were virtually the same and that considerable more error was produced in the 10 second interference condition.

These interaction relationships were interpreted by Marteniuk & Roy (1972b) as demonstrating that distance information and feedback from passive movements are coded, stored in short-term memory, and have retention characteristics similar to location information and feedback from active movement. Furthermore, it was suggested that the encoding and/or storage of distance information and passive movement feedback is not as precise as that of the other two variables. In summary, it appears that information from passive movement and distance cues are capable of being used for movement reproduction, but not to the same extent as information from active movement and location cues.

Models of MSTM

Pepper & Herman (1970) as a result of their research formulated a model of MSTM to account for their results. Their four experiments produced evidence of interference effects in motor short-term memory occuring as a result of both interpolated mental activity and task-related motor tasks. Evidence for the decrease in recall over unfilled retention intervals was also found. Consequently, Pepper & Herman (1970) postulated a two-process model of MSTM incorporating both decay and interference effects. One process involved the change over time in the represen-tation (memory trace) of the intensity or extent of the criterion motor act in the direction of lesser intensity or lesser extent. The second process involved an alteration in the representation of the criterion motor act intensity or extent by proprioceptive stimulation arising either from general changes in the level of muscle tension or from additional specific motor acts. The alteration was seen as representing the average effects of the proprioceptive stimulation arising from the criterion motor act, the interpolated motor act, and the level of prevailing muscle tension. The model was considered to have some resemblance to the two-process acid-bath theory combining decay and interference features as proposed by Posner & Konick (1966a) for verbal STM.

Since Laabs (1973) found only weak support for the assimilation model proposed by Pepper & Herman (1970), he formulated an alternative model. This model calls for two modes of storage in MSTM, one mode using a kinesthetic memory code which is subject to spontaneous forgetting and the other mode using a central memory code which is subject to forgetting when rehearsal is blocked. Laabs proposed that as a kinesthetic trace decays or as a central memory trace becomes subject to interference, the S is less able to made a perfect reproduction and that VE is an appropriate index of the decay and interference effects.

The model proposes an assimilation effect, similar to that of the Pepper & Herman model, to occur for both modes of storage, but the underlying processes assumed to be involved are completely different from those envisioned by Pepper & Herman. A reproduction is made in reference to an average or central movement in addition to the memory trace of the given movement and the CE in reproduction of a particular movement length is interpreted in terms of the influence of this referent movement on the reproductions. The referent movement is made up from the combination of movements to be reproduced and is similar in concept to the adaptation level over the set of movements to be reproduced. It is proposed that with forgetting, whether due to decay within the kinesthetic mode of storage or due to interference within the central mode of storage, more emphasis will be given to the referent movement or adaptation level during reproduction. As a result there will be an assimilarion toward the central movement position when the location cue is used or toward the central movement distance when the distance cue is used.

When the kinesthetic mode of storage is used, Laabs assumes that the emphasis given to the adaptation level will change over a retention interval. When the central mode of storage is used, Laabs postulates the kinesthetic stimulation from an interpolated motor act does not interact directly with a decaying memory trace as in the Pepper & Herman (1970) model, but is viewed as another stimulus item which contributes to the referent motor act and is included in the series that determines the adaptation level. The rehearsal of an item in the central storage mode is assumed to result in no change in the emphasis placed on the adaptation level in determining the response or possibly an increase in the emphasis placed on the criterion memory trace. Thus the CE for movement location is expected by Laabs to remain more stable over an empty retention interval than movement distance. On the other hand, when rehearsal of an item in the central mode of storage is blocked, he proposed that the emphasis given to the adaptation level will change. That is, as kinesthetic location information is forgotten, the referent movement receives more emphasis during reproduction resulting in effects similar to those expected with the decay of kinesthetic distance information.

One final aspect of the present model involves the notion of consistency in reproduction which is represented by the dispersion of reproductions of the same movement length or the same category of movement length. As the memory trace of a movement fades or somehow becomes weaker, Laabs assumes that not only will assimilation to the adaptation level occur, but also the dispersion of reproductions will increase. When the S has to reproduce movements based on weak memory traces his reproductions will be more variable than if the memory traces were strong. Thus the VE is envisaged by Laabs to be an indicator of the strength of the memory trace.

Recently Marteniuk (1973) conducted a further experiment on distance and location cues to ascertain which of the two models, the assimilation model (Pepper & Herman, 1970) or the adaptation model (Laabs, 1973), has the most power in predicting the characteristics of MSTM. Right-handed male Ss (N=60) were used in the experiment. The movement apparatus consisted of a half circle of masonite board with an arc, calibrated in half degrees, drawn on it. A movement lever was attached to a nearly frictionless pivot at the midpoint of the base of the arc. Ss moved the lever in the horizontal plane by means of a handle which could be adjusted along the length of the lever. The design was a 2 X 2 X 3 X 3 factorial with repeated measures on the last factor. The between-S variables were (1) active movement or passive movement, (2) reproduction of movement distance or movement end position, and (3) delay conditions of immediate reproduction,

reproduction after 10 seconds of mental rehearsal, or reproduction after 10 seconds of successively doubling an odd two-digit number.

All Ss were blindfolded before seeing the apparatus and were stripped to the waist to prevent extraneous cues from the stretching of clothing around the shoulder joint. The general procedure for movement reproduction involved presenting S with a CM by having him move the lever in a certain direction. After holding this position for 2 seconds, S removed his hand from the handle and E repositioned the lever. S attempted to reproduce the CM when regrasping the lever on E's command. The active movement groups established their own CM within a strategy outlined by the E. During the instruction period, Ss passively held the lever while E moved the lever twice from the starting position through 150 degrees of movement. S was told to imagine this range divided up into six equal divisions. The testing began by E asking S to reproduce a movement tracing division 1,3, or 5 corresponding to 25, 75, or 125 degrees. S's response to this request served as the CM. The passive movement groups were presented the CM by E and asked to reproduce it. Each S in the passive movement groups was matched to the corresponding S in the appropriate group of the active movement condition in terms of the extent of the CMs produced by the active movement S.

Three dependent measures of performance error were analyzed; CE, VE, and AE. Analysis of all three measures was essential for comparing the results of this study to those of Pepper & Herman (1970), Laabs (1973), and other MSTM studies which have employed CE, CE and VE, and AE, respectively.

Marteniuk (1973) analyzed the three measures of error separately by an analysis of variance. VE failed to statistically differentiate groups for all the main effects except that of active and passive movement. For the most part, CE and AE followed a similar trend over the various conditions. Since AE was considered an ambiguous measurement (Schutz & Roy, 1973), the results were interpreted in terms of CE. Active movement and location cues produced superior performance over passive movement and distance cues, respectively. Mental rehearsal appeared to have an effect of inhibiting the forgetting process in that this condition produced nearly identical performance to the immediate-reproduction condition. In contrast, counting produced a decrease in performance accuracy. Movement extent demonstrated that small movements resulted in larger error than long movements. Distance and location errors paralleled each other over the three delay conditions and a similar observation was found for the active-passive delay interaction.

In light of these findings, Marteniuk (1973) formed several conclusions with respect to the storage and retention characteristics of several cues and the predictions made by the two models of MSTM (Pepper & Herman, 1970; Laabs, 1973). Firstly, VE may be unable to differentiate between the distance and location conditions, or among the three delay conditions and their interactions with other variables. He felt this finding could indicate that movement reproduction is based upon the unique characteristics of the experimental task or that VE is not a sensitive measure of the strength of the memory trace as envisaged by Laabs (1973).

Marteniuk also concluded that the movement cues manipulated in this experiment appeared to be rehearsable in a manner similar to what has been shown for visual and verbal information. These cues showed no retention loss except when a secondary task was interpolated in the retention interval. These results were in conflict with the predictions of Pepper & Herman (1970) who postulated all information should display spontaneous forgetting. However, the assimilation model does predict that interpolated mental activity should produce a positive shift in CE and this was observed in the study data. Marteniuk, therefore concluded some movement cues have access to central processing and interpolated activity tends to increase the intensity of the trace in a manner similar to that formulated by Pepper & Herman (1970).

The evidence from the study did not provide support for the modes of memory outlined by Laabs (1973). The adaptation theory predicts that distance cues do not have access to the central processing capacity and distance information should exhibit spontaneous forgetting. No such trend was found during the mental rehearsal condition for distance information in this study. The one aspect of the adaptation model supported in the present study was the central tendency effect. Long distances were undershot and short distances were overshot.

Two final conclusions from the data were drawn by Marteniuk (1973). Firstly, different movement cues are initially represented in memory in varying degrees of exactness. This is most apparent with respect to location cues over distance cues and less so for active movement cues over passive movement cues. Secondly, short movements are influenced by an interpolated activity and longer movements are not. Accordingly, short movements were felt by Marteniuk to be more dependent on the availability of central processing capacity than long movements.

Summary of Movement Cue Research

The research in MSTM has recently attempted to isolate and investigate the cues upon which movement reproduction is based rather than examine the recall of a movement per se. Studies seem to support the central processing of location cues, these cues having been the focus of attention in MSTM experiments. Since location cues have access to central processing capacity, they are rehearsable and are negatively influenced if rehearsal is inhibited. Distance cues have been the other primary concern of MSTM researchers, however, the findings are conflicting and it is difficult to establish an operational framework that accounts for distance cues in MSTM.

Some research has examined the utilization of feedback from active and passive movement for movement reproduction. It appears that passive movement cues are coded and stored in short-term memory similar to active movement cues, but not as precisely. Accordingly, it seems that information from passive movement is capable of being used for movement reproduction but not to the same extent as information from active movement.

Neither the assimilation model (Pepper & Herman, 1970) or the adaptation model (Laabs, 1973) are able to adequately account for the characteristics of cues retained in MSTM. The assimilation model is not directly concerned with movement cues and uses CE exclusively as the measure of prediction. The adaptation model seems to predict accurately the retention of location cues in MSTM but is at variance with other research in the prediction of the retention of distance cues in MSTM.

The Problem

Location cues have been extensively investigated by MSTM theorists with the results of the various experiments being in general agreement, and an understanding of the retention characteristics of location cues having been attained. Distance cues, while having been examined in numerous studies, are not sufficiently understood since the experiments have produced conflicting results and interpretations. Further investigation is warranted for attaining an understanding of the utilization of distance cues for movement reproduction and their retention characteristics in short-term memory. In addition, active and passive movement cues require further attention to confirm and supplement the results currently reported.

Other possible kinesthetic cues that may be used in movement reproduction include torque, velocity, and direction. Torque is currently being examined (Leavitt, 1974) and velocity information is difficult to isolate as a movement cue since it is confounded with the variable of timing. Consequently, the cue that may be important in movement reproduction that should be investigated next is movement direction.

The purpose of this study was to examine distance and direction information as cues upon which movement distance and direction reproduction is based, and examine them in terms of the predictions of present MSTM models or perhaps formulate an alternative model. The retention characteristics of active and passive movement cues were also investigated.

Experimental Hypotheses

The following hypotheses were formulated and based on a review of the relevant literature as discussed in the previous sections. Separate hypotheses were constructed for the movement cues examined; direction, distance, active and passive cues. The hypotheses were constructed in relation to the four types of measures analyzed; $\overline{CE}$, VE, $\overline{AE}$, and AV.

Direction

1. Active direction movement cues provide more accurate and precise direction reproduction than passive direction movement cues ($p < .05$).
2. Direction cues are most accurately and precisely utilized for movement reproduction under the conditions of immediate reproduction (IR), mental rehearsal (MR), and random movement (RD), and least under the condition of counting (CB) ($p < .05$).
3. Direction cues are most accurately and precisely utilized for movement reproduction at an angle of 45°, least at an angle of 135°, with reproduction at an angle of 90° falling somewhere between the other two

angles ($p < .05$).

4. Active and passive direction movement reproduction are not differentiated by the various retention intervals ($p < .05$).
5. Active and passive direction movement reproduction are not differentiated by three angles ($p \leq .05$).

Distance

1. Active distance cues provide more accurate and precise movement reproduction than passive distance movement cues ($p < .05$).
2. Distance cues are most accurately and precisely utilized for movement reproduction under the conditions of IR, MR, and RD, and least under the condition of CB ($p < .05$).
3. Distance cues are most accurately and precisely utilized for movement reproduction at an angle of 45°, least at an angle of 135°, with reproduction at an angle of 90° falling somewhere between the other two ($p < .05$).
4. Active and passive distance movement reproduction are not differentiated by the various retention intervals ($p < .05$).
5. Active and passive distance movement reproduction are not differentiated by the three angles ($p < .05$).

Active movement cues contain two sources of information concerning the CM, facilitating it's reproduction. There is the proprioceptive information provided by the muscle and joint receptors which is inherent in an intact nervous system. There is also information, termed an efferent copy, which is a central representation of the consequences of motor activity. This efferent copy is not sensory in origin but carries information concerning motor commands. Passive movement does not include an efferent copy since no motor command is issued to initiate and control the movement.

The formation of the memory trace upon which movement reproduction is based and the accuracy of movement reproduction are two separate functions and not necessarily dependent upon each other. Nevertheless, it is logical that a strong memory trace should facilitate accurate movement reproduction, providing the standard or criterion level which the trace represents is similar to or the same as the desired or criterion movement.

The hypotheses for direction were based on the results of research conducted on location cues. Location cues are recognized by MSTM theorists as being readily and effectively employed in movement reproduction. Since it would seem that direction is an important component in movements, it is hypothesized that direction cues should show the same retention characteristics as location cues movement reproduction. The first hypotheses for direction and distance were formulated from the studies of Marteniuk & Roy (1972b) and Marteniuk (1973), that reported smaller movement reproduction error was associated with active movement cues than passive movement cues.

Hypothesis two for direction was formulated from several studies on location cues. Laabs (1973) investigated the retention characteristics of location cues over conditions involving immediate reproduction, 12 seconds of rest, 12 seconds of interpolated counting, and 12 seconds of an interpolated spatial reasoning task. He concluded that location cues seem to be rehearsable in some manner as long as processing capacity is available, as in the first two conditions. If rehearsal is inhibited, as in the third and fourth conditions, forgetting resulted. Marteniuk & Roy (1972b) and Marteniuk (1973) found similar results, rehearsal tended to maintain the strength of the memory trace while it was altered from its original form by interpolated mental activity. Hypothesis two for distance was formulated from the work of Marteniuk (1973). Distance cues were reported to be centrally represented and rehearsable similar to location cues. This finding was in direct opposition to the spontaneous decay of distance information over time postulated by Laabs (1973), however it concurred with the results of Marteniuk & Roy (1972b). Consequently, this hypothesis was formed on the most recent research, but with some reservation since the MSTM literature has shown conflicting results.

The third hypotheses for direction and distance were formulated from the work on movement accuracy (Brodgen et al., 1949; Begbie, 1959). It was shown that movements separated by 180^{o} were equal in accuracy with right-handed movements of 45^{o} being most accurate and movements of 135^{o} being least accurate.

The fourth hypotheses for direction and distance were formulated from the research of Marteniuk & Roy (1972b) and Marteniuk (1973) that reported the interaction of the active-passive (set) conditions with the retention interval conditions failed to differentiate between the utilization of active and passive movement cues for movement reproduction.

The fifth hypotheses for direction and distance were formulated with respect to the finding for Set X Retention Interval conditions (Marteniuk, 1973), since the Set X Angles Interaction is unique to the present study. It was hypothesized that the differences reported in movement accuracy tracking experiments (Begbie, 1959) would not be further differentiated by the absense of an efferent copy of the motor command, thereby coinciding with the results for the Set X Retention Interval Interaction.

CHAPTER III

METHODOLOGY

Sample

The Ss used in the testing were 80 male volunteers from Forster Secondary School, Windsor, with a mean age of 16.75 years (SD = 1.25 years). Other than the fact that they had to be right-handed, no restrictions were placed on their selection.

Apparatus

The experimental equipment, shown in Figures 1 and 2 consisted of a 3/4 " birch plywood base [A] , 3' X 4' . On this was drawn a half circle (14" radius) [B] with the midpoint of the baseline being 3/4" from the edge along one length of the wooden base. The half circle was calibrated in degrees. The wooden base was mounted flush with a wooden (maple) arm rest, 2 3/4" X 6 1/2" X 48" [C] . A pad of paper 18" X 24" [D] , on which movements were recorded, was fastened to the wooden base, inside the half circle, by a 3/4" angle iron bar [E] , 24" in length. The edge of the bar formed the baseline of the half circle.

*[ ] indicates the piece of the apparatus being discussed, as shown in Figures 1 and 2.

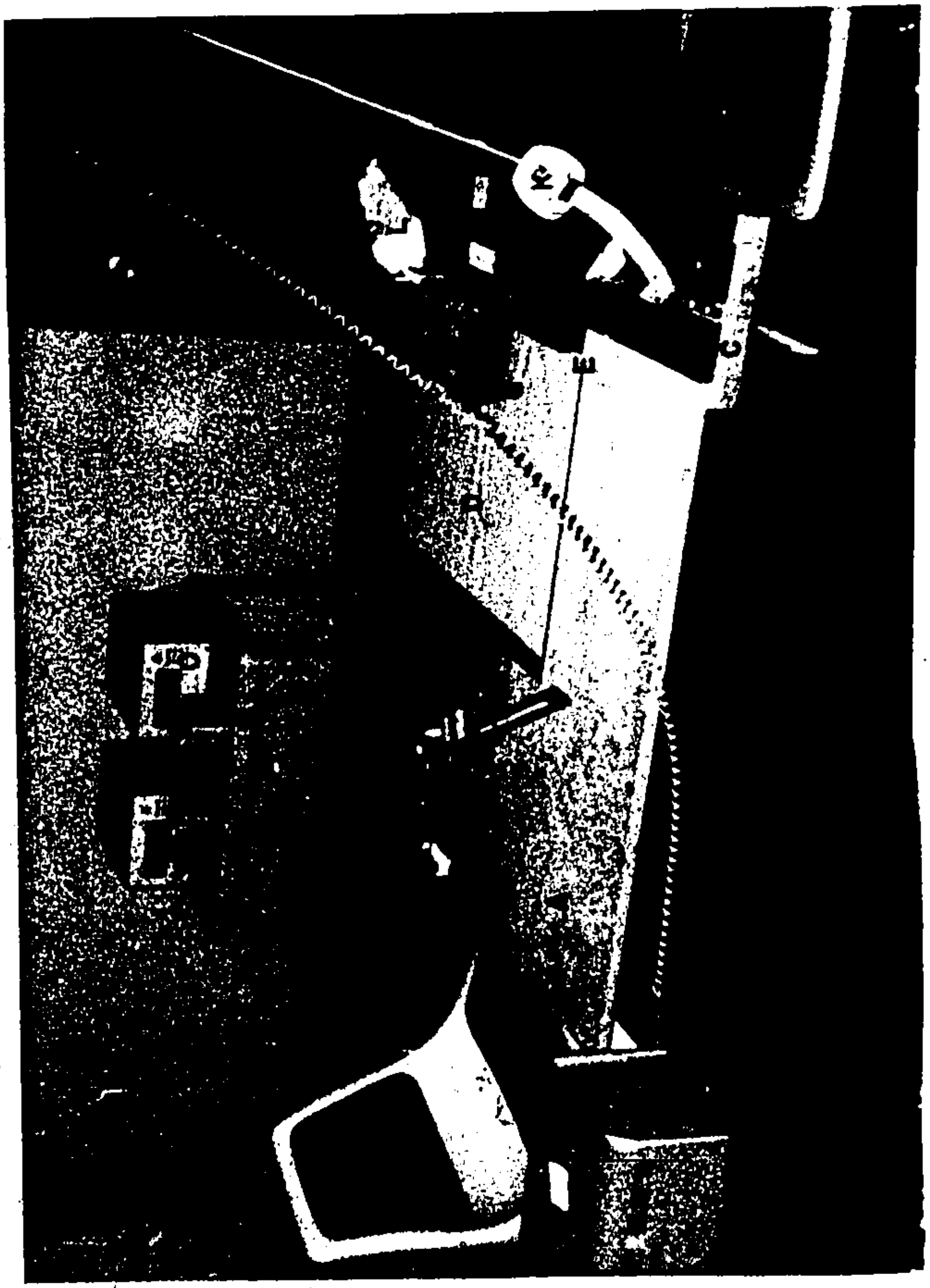

FIGURE I. APPARATUS

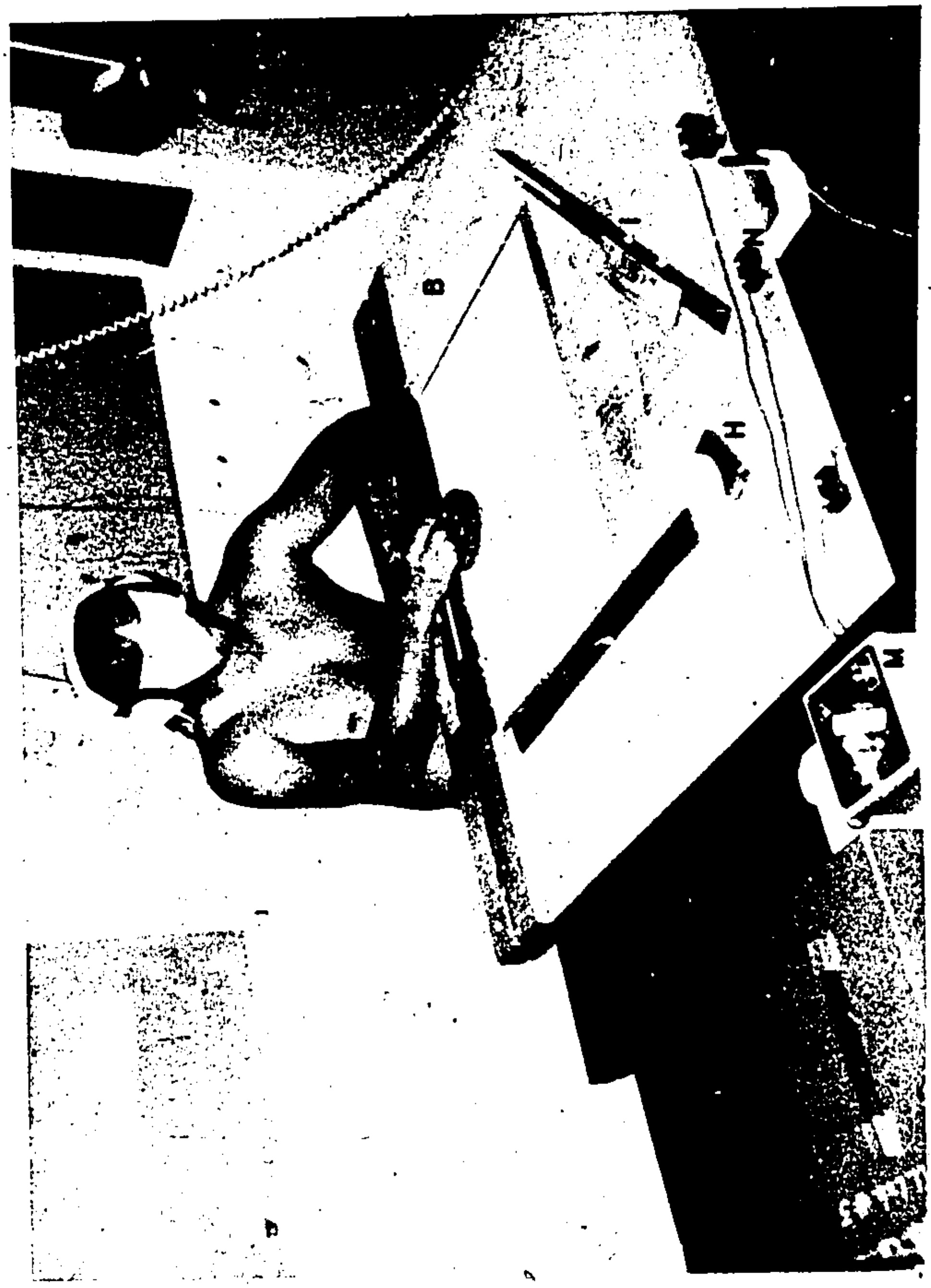

FIGURE 2. APPARATUS

A sheet metal movement platform 18" X 24" [F] was placed under the sheet of paper on which the movements were recorded.

S made movements with a handle [G] which consisted of a 3/4" X 3 1/2" nipple, fitted into a 3/4" floor flange, which was mounted on a circular (5" diameter) 3/4" maple plywood base. The handle moved on four ball-bearing rollers. In the center of the base was a 1/4" hole in which a pen was fitted to mark the movements of S .

The equipment employed in the various conditions included a 3/4" birch plywood random movement marker (1 3/4" X 3 3/4") [H] that permitted E to randomly move S starting from the end-point of the CM and terminating at the same point. A movement direction bar [I] consisting of a 27" length of 3/4" angle iron with a metal handle and an edge calibrated in mm., was used to present the CMs to S in some of the study conditions.

A General Radio Company random noise generator (type 1390-B) [J] and Daveco stereo earphones [K] were employed to eliminate auditory cues. A cloth blindfold [L] eliminated vision. Two Meylan Stopwatch Corporation time/ delay timers [M] were used to indicate the length (sec.) of the retention interval and the inter-trial-interval. Limit switches [N] and time / pulse timers [O] measured the duration (sec.) of the criterion and reproduction movements.

Experimental Design

The design was a 2 X 4 X 3 factorial with repeated measures on the last factor for $\overline{AE}$, AV, $\overline{CE}$, and VE . The 80 Ss were systematically assigned to the eight independent groups. The between-S variables were (1) movement sets of active or passive movement and (2) retention intervals of immediate reproduction, reproduction after 10 seconds of mental rehearsal, reproduction after 10 seconds of random movement, and reproduction after 10 seconds of interpolated counting. The within -S variable was movement direction with three different degrees being employed. Each S was given six consecutive trials at each of the three movement directions with the directions being randomly ordered among Ss.

Procedure

S was blindfolded and had white noise presented to him through earphones to eliminate visual and auditory cues. S was also stripped to the waist to prevent extraneous cues from the stretching of clothing around the shoulder joint. S was seated in front of the apparatus which was covered to prevent him from gaining orientation cues from the equipment. The handle was moved by S grasping it and moving his arm away from the body in the horizontal plane.

The general procedure for active movement reproduction (changed slightly for specific experimental conditions) involved presenting S with a CM by having S move the handle in a specific direction. This movement was also of a specific distance requirement, four inches. After making the CM, the retention interval began after a one second interval. During the retention interval S continued to grasp the handle. On the command from E, S attempted to reproduce the CM (direction and distance). The end-point of the CM was the starting-point of the RM. Location cues were, therefore, irrelevant for movement reproduction. S was instructed to make the movements slowly and therefore ballistic movements were eliminated and velocity cues were relatively constant. There was a 30 second ITI to insure no PI would occur.

During the initial instruction period for the active movement groups, Ss passively held the apparatus handle while E moved the handle twice along the line representing 0° (the left side of the apparatus baseline) and then twice along the line representing 180° (the right side of the apparatus baseline). These movement extents were each four inches. S was then told to imagine the range between these angles divided into four equal parts with direction No. 1 being 1/4 of the range, No. 2 being 1/2 of the range, and No. 3 being 3/4 of the range. Testing then began by E asking S to produce direction 1,2, or 3 with a straight line, and if S was accurate he produced a line with the handle four inches in length at 45, 90, and 135 degrees, respectively. The response of S to this request served as the CM which S was asked to recall.

The procedure for the passive group was identical to the active movement group with the following exceptions. The CMs for S were presented by S passively holding the handle while E moved it along a set direction through a set length. These were derived from matching each S in the passive group to corresponding S (same retention interval, distance, and direction) in the active movement group in terms of the direction and extent of the CM produced by the active subject. In this way the active and passive conditions were the same in terms of the extent and direction of CMs.

To insure there was minimal difference between the CMs of the active and passive movement groups, the passive movement circle used to present the direction to the passive group was calibrated in half degrees. Furthermore, the movement direction bar employed to move the passive movement group a given extent was calibrated in mm.

Between the CM and RM there was three retention intervals. The immediate reproduction condition involved S immediately reproducing the CM after the one second hold at the CM end-point. S in the mental rehearsal condition was instructed to think about the extent and direction of the movement for 10 seconds and on the command of E reproduced the movement (extent and direction). The random movement condition involved S being passively moved by E through a series of random movements for 10 seconds. To insure each S was moved through the same series of RMs, the movements were made to a set pattern of points on the passive movement circle. The S was then returned to the CM end-point at the termination of the 10 seconds, and then on the command of E, S reproduced the CM. The counting condition involved S counting backwards by three from a number of the following list: 97,93,89,85,77,71,69,63,57,55,47,41,35,33,29,27. S (self-paced) counted aloud during this condition beginning by repeating the number presented by E, and continuing for 10 seconds until a buzzer sounded. At the end of the 10 seconds, on the command from E, S reproduced the CM.

Before the actual testing was initiated, S was requested to repeat the instructions[2] to E to insure that S understood the requirements of the task.

Data Analysis

Since it is proposed that error detection and memory trace processes must be examined in KSTM, and that

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[2] See Appendix A.

these processes are represented by two separate distributions of scores, four dependent variables were used in this study. $\overline{CE}$ and VE were employed as indicies of the error detection mechanism and $\overline{AE}$ and AV used as indicies of the state of the memory trace.

It is difficult to control timing as a cue upon which movement reproduction is based. Therefore, ancillary information on timing was gathered to determine if Ss were using timing as a cue in the present study. Times (sec.) for the duration of the CM and duration of the RM were recorded for each trial and a correlation for the two sets of movement times was calculated.

CHAPTER IV

RESULTS

Since $\overline{CE}$, VE, $\overline{AE}$ and AV were examined for both direction and distance, the results were presented separately for each variable. The only interactions from the ANOVAs on the dependent variables discussed were those that were experimentally meaningful in terms of the Hypotheses of the study, however all ANOVA Tables are contained in Appendix B.

Error Detection Processes

Direction

As can be seen from the F ratio for $\overline{CE}$ (Table 1), the main effect for Movement Set was not significant ($p < .05$), the mean values for active movement and passive movement being 3.49 degrees and -0.25 degrees, respectively[3]. The Retention Interval also was not significant ($p < .05$), the mean values, in degrees, for the four retention conditions being IR = -3.17, MR = 0.64, RD = 5.97, and CB = 3.05. The main effect for Angle of Movement was

[3] Appendix C contains Tables of the mean values for all the dependent variables over all the conditions examined.

TABLE I

F RATIOS FOR THE MAIN EFFECTS AND INTERACTIONS OF $\overline{CE}$, VE, $\overline{AE}$, AND AV FOR DIRECTION AND DISTANCE

	Appendix Table	A Movt Set	B RI	AXB MS X RI	C Angle	AXC MS X Ang	BXC RI X Ang	ABC
Direction								
CE	I	2.06	2.19	0.10	33.52**	2.04	3.71**	0.66
VE	II	20.32**	3.22*	0.93	1.30	4.09*	0.77	0.57
AE	III	36.17**	8.66**	2.12	9.29**	3.53*	3.04**	1.54
AV	IV	19.45**	5.82**	1.76	2.42	2.12	1.31	0.68
Extent								
CE	V	14.40**	0.99	0.58	16.39**	0.69	0.77	0.56
VE	VI	6.41*	2.63	1.70	4.07*	0.56	1.01	0.70
AE	VII	0.63	0.79	2.08	8.44**	3.23*	0.42	0.65
AV	VIII	0.44	0.85	1.15	2.71	0.38	0.58	0.77

* $p < .05$
** $p < .01$

significant, $F(2,144) = 33.52$, $p < .01$. A post hoc analysis using the Tukey (a) Test indicated that the error detection level selected by S differed significantly ($p < .05$) among the three angles (Table II). $\overline{CE}$ was closest to the criterion value for 90^{0} (0.08 degrees) and furthest for 45^{0} (4.60 degrees). Neither the Movement Set X Retention Interval Interaction nor the Movement Set X Angle of Movement Interaction were significant ($p < .05$), as shown in Table I.

For VE the analysis of variance revealed that Movement Set was significant, $F(1,72) = 20.32$, $p < .01$ (Table I). The mean value for Active Movement was 13.69 degrees and the mean value for Passive Movement was 19.90 degrees. The Retention Interval was also significant, $F(3,72) = 3.22$, $p < .05$ (Table I). Further analysis by the Tukey (a) Test ($p < .05$) demonstrated that the sensitivity of the error detection process was similar for the IR and MR conditions with mean values of 15.50 degrees and 14.07 degrees, respectively. In contrast, the sensitivity of the error detection process decreased significantly with interpolated RD (19.55 degrees), and somewhat to a lesser degree with interpolated CB (18.07 degrees) (Table III). The Movement Set X Retention Interval Interaction for VE was not significant ($p < .05$) as disclosed in Table I. However, the Movement Set X Angle of Movement Interaction was significant, $F(2,144) =$

TABLE II

DIFFERENCES BETWEEN THE ANGLE OF MOVEMENT CONDITIONS FOR THE $\overline{CE}$ OF DIRECTION (TUKEY (A) TEST PROCEDURE)

Totals (degrees)	90°	135°	45°
	0.7	-239.2	368.4
90°		-238.5*	367.7*
135°			629.2*

* Significant, $p < .05$.

TABLE III

DIFFERENCES BETWEEN THE RETENTION INTERVAL CONDITIONS FOR THE VE OF DIRECTION (TUKEY (A) TEST PROCEDURE)

Totals (degrees)	MR	IR	C	RM
	281.5	310.0	361.4	391.0
MR	-	28.5	79.9*	109.5*
IR			51.4	81.0*
C				29.6

* Significant, $p < .05$.

4.09, $p < .05$, and the interaction is presented in Figure 3. At 90° there was an increase in the sensitivity of the error detection process for the Active Movement Group (VE= 3.96 degrees) over that of 45° (VE = 5.01 degrees) but not for the Passive Movement Group as demonstrated by an analysis of the simple effects (Table IV) . At 135° the sensitivity again decreased somewhat for the Active Movement Group (VE = 4.72 degrees). In contrast, the sensitivity of the error detection process of the Passive Movement Group decreased steadily from 45° through 135°, the values for VE being 5.87 degrees, 6.86 degrees, and 7.16 degrees, respectively.

Extent

The F ratio for $\overline{CE}$ indicated that the Passive Movement Group ($\overline{CE}$ = 0.02) formulated an error detection level more closely approximating the criterion value than the Active Movement Group ($\overline{CE}$ = -4.51), $F(1,72) = 14.40$, $p < .01$. The Angle of Movement for $\overline{CE}$ was also significant, $F(1,72) = 16.39$, $p < .01$ (Table I). The Tukey (a) Test ($p < .05$) (Table V) revealed that S formulated his error detection level almost identical with the criterion value ($\overline{CE}$ = +0.08 cm.) when making movements at 90°. S significantly shifted this detection level in a negative direction when reproducing movements at 45° ($\overline{CE}$ = -0.78 cm.), and shifted it further still in the same direction when reproducing movements at 135° ($\overline{CE}$ = -1.37 cm.). The

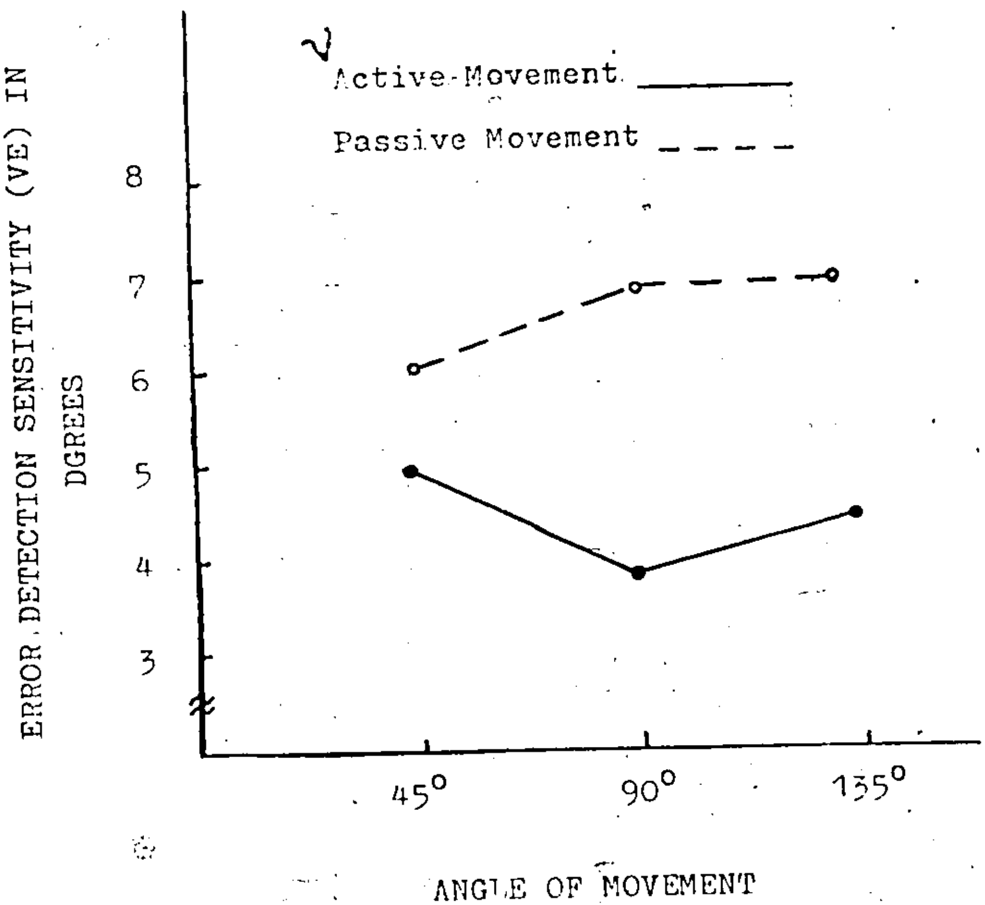

Figure 3. Mean Variable Error Of The Movement Set By Angle Of Movement Interaction In Degrees For Direction.

TABLE IV

MOVEMENT SET X ANGLE OF MOVEMENT INTERACTION FOR VE OF DIRECTION (ANALYSIS OF SIMPLE EFFECTS)

Source	SS	df	MS	F
a @ c_1	14.88	1	14.88	2.66
a @ c_2	168.49	1	168.49	30.19*
a @ c_3	118.82	1	118.82	21.29*
c @ a_1	23.62	2	11.80	2.12
c @ a_2	36.56	2	18.28	3.28*
ERROR	803.49	144	5.58	

* Significant, $p < .05$.

TABLE V

DIFFERENCES BETWEEN THE ANGLE OF MOVEMENT CONDITIONS FOR THE $\overline{CE}$ OF EXTENT (TUKEY (A) TEST PROCEDURE)

Totals (cm.)	90^{o} -6.8	45^{o} -62.8	135^{o} -110.3
90^{o}		56.0*	103.5*
45^{o}			47.5*

* Significant, $p < .05$.

Retention Interval for $\overline{CE}$ was disclosed to be non-significant ($p < .05$); however, S established an error detection level that was less than the criterion value for all four retention conditions (IR = -1.60 cm., MR = -3.09 cm., RD = -0.90 cm., and CB = 3.09 cm), and this trend was similarily apparent for Angle of Movement and Movement Set. Movement Set X Retention Interval and Movement Set X Angle of Movement Interactions for $\overline{CE}$ were not significant ($p < .05$) as given in Table I.

As can be seen from the F ratios for VE, the main effects for Movement Set and Angle of Movement were significant ($p < .05$). The corresponding values for VE were $F(1,72) = 6.41$ and $F(2,144) = 4.07$. The Tukey (a) Test (Table VI) showed that at 90° the error detection process employed by S was most sensitive (VE = 1.44 cm.), and least sensitive at 45° (VE = 1.73 cm.). The sensitivity of the error detection process at 135° (VE = 1.54 cm.) did differ significantly from either of the other two angles ($p < .05$). The Retention Interval for VE just failed to reach the conventional significance level and was not analyzed by the Tukey (a) Test. The Movement Set X Retention Interval and Movement Set X Angle of Movement Interactions for VE also did not reach significance ($p < .05$) as shown in Table I.

TABLE VI

DIFFERENCES BETWEEN THE ANGLE OF MOVEMNT CONDITIONS FOR THE VE OF EXTENT (TUKEY (A) TEST PROCEDURE)

Totals (cm.)	90° 115.4	135° 123.5	45° 138.4
90°		8.1	23.0*
135°			14.9

* Significant, $p < .05$.

TABLE VII

DIFFERENCES BETWEEN THE RETENTION INTERVAL CONDITIONS FOR THE $\overline{AE}$ OF DIRECTION (TUKEY (A) TEST PROCEDURE)

Totals (degees)	MR 299.8	IR 412.0	C 457.5	RM 526.5
MR		112.2*	157.7*	226.7*
IR			45.5	114.5*
C				69.0*

* Significant, $p < .05$.

Memory Trace Processes

Direction

The F ratios for $\overline{AE}$ demonstrated that the main effects for all independent variables, Movement Set, Retention Interval, and Angle of Movement were significant ($p < .01$) the values being $F(1,72) = 36.17$, $F(3,72) = 8.66$, and $F(2,144) = 9.29$, respectively (Table I). A post hoc anlaysis using the Tukey (a) Test ($p < .05$) indicated that MR ($\overline{AE}$ = 14.90 degrees) decreased forgetting compared to IR ($\overline{AE}$ = 20.60 degrees), while RD ($\overline{AE}$ = 26.32 degrees) produced a significant decrease in the accuracy of movement reproduction. CB did not increase forgetting ($\overline{AE}$ = 22.87 degrees) in that this condition produced a similar performance to the IR condition (Table VII). Most accurate direction reproduction occurred at an angle of 90° ($\overline{AE}$ = 5.80 degrees) with reproduction accuracy at 45° ($\overline{AE}$ = 7.39 degrees) and 135° ($\overline{AE}$ = 8.0 degrees) not differing from each other (Table VIII). The F ratio revealed that the Movement Set X Retention Interval Interaction (Table I) was not significant ($p < .05$). The next interaction of interest was the Movement Set X Angle of Movement Interaction for $\overline{AE}$, shown in Figure 4. The accuracy of direction reproduction as determined by an analysis of the simple effects, (Table IX) increased for both Active and Passive Movement Groups when the angle

TABLE VIII

DIFFERENCES BETWEEN THE ANGLE OF MOVEMNT CONDITIONS FOR THE $\overline{AE}$ OF DIRECTION (TUKEY (A) TEST PROCEDURE)

Totals (degrees)	90^o	45^o	135^o
	464.3	591.6	640.0
90^o		127.3*	175.7*
45^o			48.4*

* Significant, $p < .05$.

TABLE IX

MOVEMENT SET X ANGLE OF MOVEMENT INTERACTION FOR $\overline{AE}$ OF DIRECTION (ANALYSIS OF SIMPLE EFFECTS)

Source	SS	df	MS	F
a @ c_1	60.46	1	60.46	5.46*
a @ c_2	232.36	1	232.36	20.96*
a @ c_3	415.87	1	415.36	37.96*
c @ a_1	119.10	2	59.55	5.37*
c @ a_2	164.02	2	82.00	7.40*
ERROR	1595.68	144	11.08	

* Significant, $p < .05$.

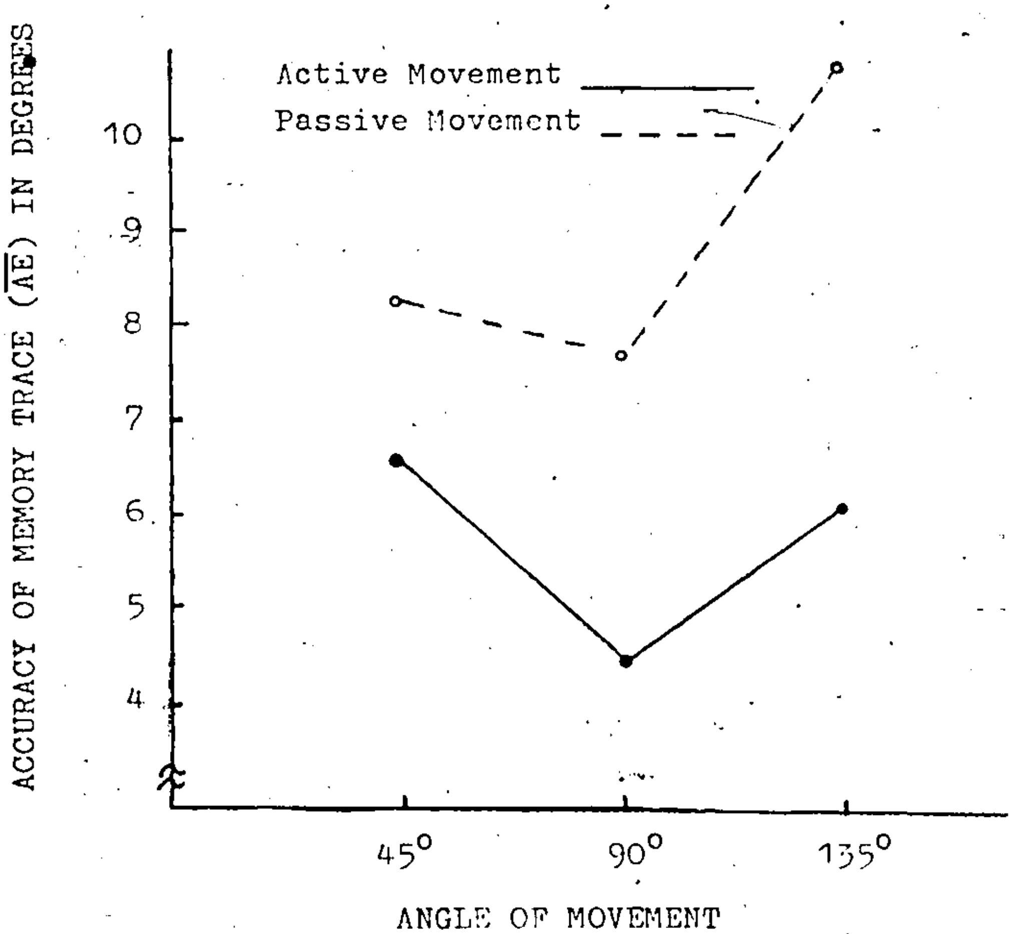

Figure 4. Mean Absolute Error Of The Movement Set By Angle Of Movement Interaction In Degrees For Direction.

of movement shifted from 45^{o} to 90^{o}, and then decreased again when the angle of movement shifted from 90^{o} to 135^{o}. However, the increase in the accuracy of reproduction for the Active Movement Group ($\overline{AE}$ = 4.10 degrees) at 90^{o} was significantly greater than for the Passive Movement Group ($\overline{AE}$ = 7.50 degrees). At 135^{o} the Active Movement Group only showed a slight decrease in direction reproduction accuracy ($\overline{AE}$ = 5.72 degrees) whereas the direction reproduction accuracy for the Passive Movement Group ($\overline{AE}$ = 10.28 degrees) decreased beyond that of their performance at 45^{o}.

For AV, the F ratio disclosed a stronger memory trace for the Active Movement Group (AV = 10.45 degrees) compared to the Passive Movement Group (AV = 14.55 degrees), F (1,72) = 19.45, $p < .01$ (Table I). The main effect for Retention Interval was also significant, F (3,72) = 5.82, $p < .01$. Using the Tukey (a) Test ($p < .05$) it was found that MR maintained the strength of the memory trace to a degree nearly identical with that of IR (MR = 10.67 degrees, IR = 10.77 degrees). The memory trace weaken appreciably when interpolated CB filled the retention interval (AV = 13.22 degrees), and continued this trend further (AV = 15.36 degrees) for the RD condition (Table X). The Movement X Retention interval and Movement Set X Angle of Movement Interactions for AV failed to reach significance ($p < .05$) as presented in Table I.

TABLE X

DIFFERENCES BETWEEN THE RETENTION INTERVAL CONDITIONS FOR THE AV OF DIRECTION (TUKEY (A) TEST PROCEDURE)

Totals (degrees)	MR 213.4	IR 215.4	C 264.4	RM 307.3
MR		2.0	51.0	93.9*
IR			49.0	91.9*
C				42.9

* Significant, $p < .05$.

TABLE XI

DIFFERENCES BETWEEN THE ANGLE OF MOVEMENT CONDITIONS FOR THE $\overline{AE}$ OF EXTENT (TUKEY (A) TEST PROCEDURE)

Totals (cm.)	90° 165.4	45° 189.6	135° 213.1
90°		24.2	47.7*
45°			23.5

* Significant, $p < .05$.

Extent

For $\overline{AE}$, the F ratios revealed that both Movement Set (Active Movement = 7.34 cm., Passive Movement = 6.86 cm.) and Retention Interval (IR = 6.59 cm., MR = 7.14 cm., RD = 7.85 cm., and CB = 6.82 cm.) were not significant ($p < .05$) (Table I). The Angle of Movement for $\overline{AE}$ was significant, F (2,144) = 8.44, $p < .01$. The Tukey (a) Test (Table XI) showed that S was most accurate in making movement reproductions at 90^{o} ($\overline{AE}$ = 2.06 cm.). The performance of S at 45^{o} ($\overline{AE}$ = 2.37 cm.) was not significantly different from either of the other two angles ($p < .05$). The Movement Set X Retention Interval Interaction was not significant ($p < .05$) for $\overline{AE}$ (Table I). The Movement Set X Angle of Movement Interaction was significant, F (2,144) = 3.23, $p < .05$ (Figure 5). An analysis of the simple effects (Table XII) showed the accuracy of movement reproduction was nearly identical for the Active Movement Group ($\overline{AE}$ = 2.40 cm.) and the Passive Movement Group ($\overline{AE}$ = 2.34 cm.) at 45^{o}. At 90^{o} the performance of the Active Movement Group ($\overline{AE}$ = 1.99 cm.) improved more than the Passive Movement Group ($\overline{AE}$ = 2.14 cm.). When the angle of movement was then shifted to 135^{o}, the reproduction accuracy of the Active Movement Group ($\overline{AE}$ = 2.95 cm.) deteriorated substancially, whereas the performance of the Passive Movement Group ($\overline{AE}$ = 2.37 cm.) returned to approximately the same accuracy level as

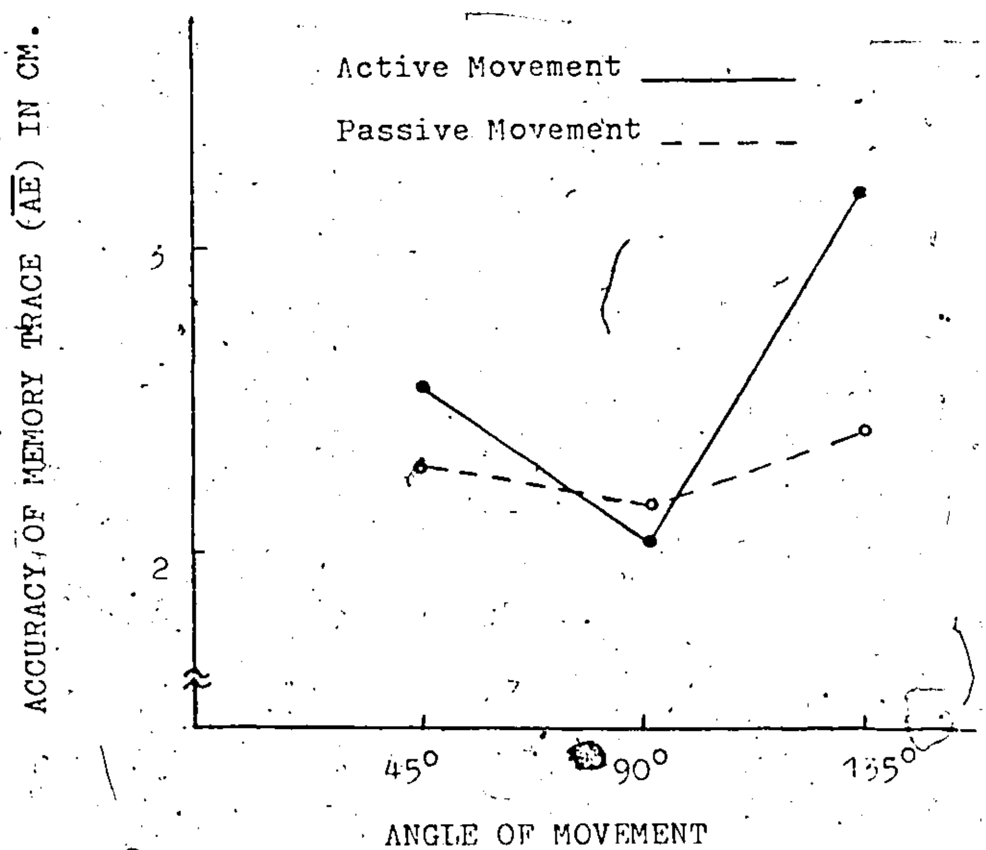

Figure 5. Mean Absolute Error Of The Movement Set By Angle Of Movement Interaction In Cm. For Extent.

TABLE XII

MOVEMENT SET X ANGLE OF MOVEMENT INTERACTION FOR $\overline{AE}$ OF EXTENT (ANALYSIS OF SIMPLE EFFECTS)

Source	SS	df	MS	F
a @ c_1	0.30	1	0.30	0.35
a @ c_2	0.40	1	0.40	0.47
a @ c_3	6.60	1	6.60	7.84*
c @ a_1	17.90	2	8.95	10.63*
c @ a_2	1.90	2	0.95	1.06
ERROR	121.18	144	0.84	

* Significant, $p < .05$.

exhibited at 45°.

The F ratio for AV (Table I) of all three of the independent variables - Movement Set, Retention Interval, and Angle of Movement - failed to reach significance ($p < .05$). Furthermore, the Movement Set X Retention Interval and Movement Set X Angle of Movement Interactions were also non-significant ($p < .05$) as shown in Table I.

Timing

As indicated in Table XIII, the mean CM times over the three angles of movement ranged from 3.734 - 4.008 seconds while the mean RM times over the three angles of movement ranged from 3.578 - 3.590 seconds. These times confirmed that S was not making ballistic movements since ballistically the distance would have to have been travelled in less than 190 msecs. Therefore, S was able to process feedback while making the movements. S consistently took a shorter time to make the RMs than the CMs. This difference was significant for 45° movements ($p < .05$) but failed to reach the conventional level of significance for 90° and 135° movements (Table XII). S did not employ timing as a cue upon which to base the reproduction movements. This was confirmed by a correlation between the CM times and the RM times, presented in Table XIV.

TABLE XIII

MEANS, STANDARD DEVIATIONS, AND F RATIOS OF THE CRITERION AND REPRODUCTION MOVEMENT TIMES OVER ALL THE RETENTION INTERVALS AND MOVEMENT SETS

Angle	Criterion Movement (sec) $\overline{X}$	Criterion Movement (sec) SD	Reproduction Movement (sec) $\overline{X}$	Reproduction Movement (sec) SD	F Ratio
45°	4.0084	1.4929	3.5780	1.3352	15.53*
90°	3.7037	1.2577	3.5814	1.3958	1.37
135°	3.7339	1.3115	3.5901	1.4114	1.54

* Significant, $p < .05$.

TABLE XIV

CORRELATION BETWEEN THE CM TIMES AND THE RM TIMES

	CM 45°	CM 90°	CM 135°
RM 45°	0.76	0.77	0.76
RM 90°	0.73	0.74	0.77
RM 135°	0.64	0.64	0.70

A correlation coefficient of 0.766 between the two times at 45° indicated that 58 per cent of the variance in the CM times and RM times were associated. For the times at 90°, $r = 0.748$ indicated that 55 per cent of the variance was common to both movement times. At 135°, 50 per cent of the variance in the CM times and RM times were associated, $r = 0.710$.

CHAPTER V

DISCUSSION

The general purpose of this investigation was to evaluate the codability and retention characteristics of several cues proposed to underlie movement reproduction. Researchers in the area of movement reproduction originally employed $\overline{AE}$ as the dependent variable, but then initiated the use of $\overline{CE}$ feeling it more adequately described the distribution of error scores. Schutz & Roy (1972) next argued that to describe a distribution of error scores $\overline{CE}$ and VE should be employed. Accordingly, movement cue researchers have anlayzed their results in terms of these two error measures, however various interpretations of the meaning of $\overline{CE}$ and VE have been used. This has led to confusion in the KSTM literature.

Offering an alternative to the existing confusion, it is proposed that $\overline{AE}$ and AV describe a different distribution of scores which contains information about the retention charactersitics of movement cues not contained in the $\overline{CE}$, VE distribution. Correlations (Appendix C) confirmed this proposal, the ~~average~~ variance of $\overline{AE}$ that was associated with both $\overline{CE}$ and VE being 8 per cent for direction and 7 per cent for extent. It also can be argued from simple logic that $\overline{AE}$ and $\overline{CE}$ provide separate information about the retention characteristics of cues. $\overline{CE}$ indicates the direction of the deviation from the criterion value but has the tendency of centralizing the error scores about that criterion value, thus minimizing the size of the error. In contrast, $\overline{AE}$ contains no information concerning the direction of the deviation from the criterion value but gives the maximum magnitude of the error. Therefore, $\overline{AE}$ and AV are proposed to provide information concerning the state of the memory trace and $\overline{CE}$ and VE provide information about the error detection mechanism employed by S in movement reproduction. Both distributions should be examined. It is analogise to heart rate and stroke volume being indicies of cardiac output. A physiologist measuring one and not the other obtains only a portion of the total available information.

The duration of the criterion and reproduction movements was measured to determine whether timing was being used as a cue for movement reproduction. This was undertaken since it was difficult to control timing as a possible reproduction cue. Correlations between the CMs and RMs indicated timing was not being employed as a cue. Therefore, it is assumed that Ss were basing their movement reproductions on the cues provided, direction and distance.

Since the interpretation of the dependent variables in this study differs from previous investigations, the results of other experiments are not directly comparable to the present findings. Nevertheless, the general conclusions reached by other researchers can be considered with respect to the conclusions drawn from the present data.

The results of the present study were presented in terms of the two processes involved in movement reproduction for direction and distance movement cues. This was done in order to demonstrate the use of direction and distance cues for movement reproduction within the framework of the error detection and memory trace processes. However, since the purpose of this study is to examine the retention characteristics of these movement cues, a slightly different approach will be taken in this chapter. Direction, distance, and active and passive cues each will be discussed separately in terms of the error detection and memory trace processes. In addition, a model of KSTM will be proposed.

Direction

The error detection level S selects and employs during the movement reproduction was not altered by a change in the Movement Set or Retention Interval. This suggests that the manner in which S uses direction cues to set the level at which a RM will be considered satisfactory with respect to deviation from the CM, is stable over the various Movement Set and Retention

Interval conditions for direction. Although Marteniuk (1973) interpreted CE as an index of forgetting, he also reported non-significant main effects for CE over similar conditions. In contrast, when the angle of movement shifted, S changed his error detection level so that the allotted deviation for movement reproduction was lowest for 90^{o} and highest for 45^{o}. Direction cues facilitate the establishment of an error detection level in a positive direction when the angle of movement is less than 90^{o} and in a negative direction when the angle of movement exceeds 90^{o}. This suggests a Central Tendency Effect for direction comparable to that observed for location and movement length by Laabs (1973).

Although a change from active to passive movement did not result in a shift in the error detection level set by S, this detection process was more sensitive for the Active Movement Group than the Passive Movement Group. An efferent copy of the motor program for the CM resulted in the establishment of a more sensitive error detection process. The sensitivity of the error detection process set by S also varied over the Retention Interval conditions. Random movement, and to a lesser degree CB, had a detrimental influence on the sensitivity of the error detection process. On the other hand, the sensitivity of the detection process did not vary as the angle of the movement shifted from 45^{o} to 135^{o}.

The error detection mechanism was influenced, as indicated by either $\overline{CE}$ or VE under all three of the independent variables employed in the study. Since the error detection mechanism is set by S, it is to be expected that changes in the type of feedback (active vs passive) and the environment would influence the level and sensitivity of the error detection mechanism. Other factors such as knowledge of results, although not investigated in this study, can be expected to also influence the error detection mechanism.

When examining the retention characteristics of direction movement cues in terms of forgetting ($\overline{AE}$), a comparison with respect to research on other movement cues, specifically location cues, can be undertaken. The performance of the Active Movement Group was superior to that of the Passive Movement Group which parallels the work of Marteniuk & Roy (1972b) and Marteniuk (1973) for location cues. Secondly, it appears that movement direction cues can be rehearsed in a manner similar to what has been observed for movement location cues (Laabs, 1973; Marteniuk, 1973). Actually, MR of direction cues produced a more accurate performance than IR, a phenomenon not reported for location cues. This suggests that direction cues are more exactly represented in memory than location cues. Support for this comes from the fact that the retention of direction cues is not influenced by interpolated activity (CB) but a similar secondary task produces forgetting for movement reproductions based on location cues (Marteniuk, 1973). Movement direction reproduction accuracy decreases significantly when the retention interval is filled with RD. This may be attributable to there being a degree of similarity (plane and extent) between the criterion and random movements since Salmoni (1971) found a similar result for distance; increased similarity of movement caused an increase in recall error. A comparison with research conducted on other movement cues is not possible since a RD condition has not been included in these studies.

The retention of movement direction cues was also altered by the angle of movement, reproduction at 90° being most accurate ($\overline{AE}$) and reproduction performance at 45° and 90° being almost identical. Therefore, direction cues from movements made at 90° are more exactly represented in memory than cues from movements made at 45° and 135°. These results are in conflict with the results of tracking experiments (Begbie, 1959) which found accuracy was greatest at about 45° and progressively deteriorated as the angle of movement increased, being lowest at about 135°. The discrepancies between the findings for the memory and tracking experiments may be due to the elimination of vision. With vision eliminated in the present study, <u>S</u> was forced to base his performance partially on past experience and the orientation of his arm movements to the rest of his body, both of which S would be most familiar with for movements at 90^{o}. These conceivably outweighed the bio-mechanical advantages of moving the arm at an angle of 45^{o} (Begbie, 1959).

The strength of the memory trace (AV) for direction cues was greater under the active movement condition than the passive movement condition, the difference again being associated with the efferent copy of the motor program. In addition, the strength of the memory trace was maintained by MR but was weaken when a secondary task was interpolated in the retention interval. The memory trace strength did not vary with the angle of movement. Therefore, it appears that the strength of the memory trace for direction cues is influenced by the type of feedback and the availability of the information processing capacity, but is not effected by what can be termed environmental factors.

The memory trace for direction movement reproduction varied over each of the three independent variables employed in the study following in each instance the trend of either $\overline{CE}$ or VE. This can be expected since direction cues are represented in memory with a high degree of exactness, and any change S makes in the level or sensitivity of the error detection mechanism will usually result in a significant corresponding change in the memory trace. Although location movement cues are not as exactly represented in memory as direction movement cues, Marteniuk (1973) reported a similar trend. His data showed the sensitivity of the error detection mechanism statistically differentiated Ss for only the active and passive movement conditions, which the error detection level failed to show. However, for the most part, there was a parallel trend between changes in the error detection level and the accuracy of the memory trace over the other conditions. These results substantiate the proposal that for a movement cue exactly represented in memory, any change in the error detection process will probably influence the memory trace.

Extent

In contrast to the results found for movement direction cues, the Passive Movement Group set an error detection level more closely approximating the criterion value than the Active Movement Group. This finding is rather unexpected since Marteniuk (1973) found no difference between the active and passive movement conditions for distance. Moreover, the CMs were relatively short (requested length 4 inches) and a Central Tendency Effect in $\overline{CE}$ - overshooting short distances and undershooting long distances - as reported by Pepper & Herman(1970) should have been evident in the results. However, instead of S setting an error detection level greater than the criterion value, a detection level less than the criterion was established. A possible explanation may be that S was asked to base his movement reproductions on both distance and direction. Since in the active movement condition S had an efferent copy of the motor program for both direction and distance for each CM, perhaps the copy of the motor program for direction in some manner interfered with the copy of the motor program for distance causing S to negatively shift his error detection level. The same result was absent from the passive movement condition because S had no efferent copy of the motor program to use for movement reproduction.

When distance cues were manipulated over retention intervals it was found that as with direction cues, S did not change the error detection level he had established. Since similar results were found for distance and location (Marteniuk, 1973), it seems that the error detection level is not influenced by the various cues examined when rehearsal is either facilitated or inhibited. When the angle of movement was changed, S did change his error detection level in a manner similar to that observed for direction movement cues; the allotted deviation for movement reproduction from the CM was lowest at 90°. However, the Central Tendency Effect evident for direction was absent for distance. At all three angles S set the detection level at a point less than the criterion value. The reason for the low $\overline{CE}$ at 90° is probably the same as that explained for direction cues; S is more familiar with making movements at right angles to the body than at the other two angles. The setting of the detection level by S at a point lower than the criterion value, a trend also observed for the retention interval conditions, can only be accounted for by the fact that S had to base his criterion levels on both distance and direction cues. The direction cues must have interfered in some manner with the distance cues, perhaps as proposed previously by means of the efferent copy of the motor program, so that S consistently set a negative detection value.

The sensitivity of the error detection mechanism was significantly different for the Active and Passive Movement Groups, the Active Group establishing a more sensitive detection process. This was probably the result of the presence of an efferent copy of the motor command for the Active Group, allowing Ss to be more consistent in setting their detection level. Marteniuk (1973) reported similar results for VE. Unlike direction movement cues, the sensitivity of the error detection process set by S for distance movement cues was not influenced by the central processing requirements of counting backwards or rehearsal during the retention interval. This may have been the consequence of S being better able to employ direction movement cues in the error detection process than distance cues, and therefore the sensitivity of the detection process may have been subject to alterations that effected the ability of S to use direction cues.

Although the above explanation of the different results found for direction and distance in terms of the sensitivity of the error detection process is logical with respect to this study, it is not applicable to the findings of other investigators. Laabs (1973) using VE reported counting was significantly different from immediate reproduction and interpolated rest for location cues but not distance cues. Marteniuk (1973) failed to obtain any significant differences for VE over various retention interval conditions. The obvious conclusion is that the sensitivity of the error detection process set by S for various retention interval conditions is based upon unique characteristics of the experimental task.

The sensitivity of the error detection process for distance varied over the three angles of movement, unlike for direction. It is expected, based on the function of servo mechanisms that external factors would influence the detection level and internal factors the sensitivity of the detection process. This was found for direction cues. The error detection process for distance cues may have deviated from this pattern because distance information is derived from a higher order synthesis of information (Marteniuk & Roy, 1972a).

The Active Movement Group and the Passive Movement Group were similar in their performance accuracy for reproducing movement distance. This is unexpected since

S set different error detection levels and changed the sensitivity of the detection process for the two conditions, and generally such a change would be accompanied by a corresponding change in the accuracy of movement reproduction. Possibly the change S initiated for the error detection level was offset by the change in the sensitivity of the detection process. This seems likely considering the error detection level deviated least from the criterion value for the Passive Movement Group while the Active Movement Group established the more sensitive detection process.

Probably the most interesting aspect of this study concerns the retention of distance cues over the various retention interval conditions. Previous research has produced conflicting results although much of the confusion has resulted from the use of different error variables to measure retention. Briefly, Laabs (1973) reported a decrease in retention after a rest interval over that for immediate reproduction of distance but little loss over that for immediate reproduction of location. When interpolated activity was added there was a large decrease in retention over that for immediate reproduction of location but no orderly change over that for immediate reproduction of distance. Marteniuk (1973) found results in direct opposition to Laabs; distance cues had access to the central processing capacity similar to location cues, and did not exhibit spontaneous forgetting. The present study indicates that distance movement cues do not exhibit spontaneous forgetting since there was no significant difference between the IR condition and the MR condition. Nevertheless, the results can also be interpreted to indicate that distance cues are not centrally represented since neither RD or CB had any influence on retention; which would be predicted if distance cues did not have access to the central processing capacity. The most logical interpretation of the results, however, is that distance movement cues are centrally represented but not as exactly as direction and probably location movement cues, and consequently reproduction of movement distance for the IR condition is relatively inaccurate. Therefore, an interpolated task such as CB or RD has a negligable effect on retention over that of IR.

The experimental data support this interpretation. The mean criterion movement length for the IR condition was 9.73 cm. while the $\overline{AE}$ for the reproduction of this criterion length was 67 per cent of the original, or 6.59 cm. It is difficult to conceive of a secondary task such as CB producing a further decrement in performance, since this would virtually indicate that S had completely forgotten the criterion movement length.

The retention of movement distance cues was altered by the angle of movement, the performance of S being most accurate at 90° and least accurate at 135°. Since similar results were observed for direction cues, it can be concluded that when vision is eliminated, S can most accurately remember movements made at an angle frequently used in daily life as compared to less familiar angles. In other words, S can most accurately reproduce movements at 90° because his ability to use the reference points of the body is most advantageous and developed for reproduction at this angle.

With respect to the strength of the memory trace for distance cues, it was found that memory trace strength did not vary over any of the conditions examined for the three independent variables. This finding is not unexpected since a similar ~~trend~~ was observed for the accuracy with which distance cues were reproduced. The present results certainly support the arguement made by Marteniuk & Roy (1972b) and Marteniuk (1973); distance cues are not represented in memory as precisely as other movement cues (direction and location) and are not capable of being used for movement reproduction to the same degree.

Active And Passive Movement Cues

The previous two sections have discussed direction and distance cues in terms of the processes involved in KSTM. Included in this discussion was the change of the error detection and memory trace processes over the conditions of active and passive movement. Marteniuk (1973), in addition to using these two Movement Set conditions for an investigation of the retention characteristics of location and distance cues, also examined the retention characteristics of active and passive movement cues. In order to draw comparisons between Marteniuk (1973) and the present research, the Movement Set conditions will be discussed as active and passive cues.

Marteniuk & Roy (1972b) reported that passive movement cues are coded and stored in short-term memory, just as active movement cues are, but not as exactly. Furthermore, they concluded that passive movement cues are capable of being used for movement reproduction, but not to the same extent as active movement cues. Marteniuk (1973) found similar results, drawing the conclusion that the two cues are initially represented in memory in varying degrees of exactness. The data from this study compares favourably with this previous research. When movement direction cues were examined, the sensitivity at which the error detection mechanism was set and the state of the memory trace differed significantly for the Active and Passive Movement Groups. Only the error detection level used by the two groups was the same. For movement distance reproduction, the Active Movement Group employed both a different error detection level and sensitivity value than the Passive Movement Group. With respect to the memory trace process, in contrast to movement direction reproduction no differences were evident for the two groups. An examination of the main effects, therefore, indicates that active and passive cues are differentiated by some manner in memory.

To determine whether active and passive movement cues are actually stored in memory differently or represented in memory differently as hypothesized by Marteniuk & Roy (1972b), the Movement Set by Retention Interval Interactions were examined. It was proposed that if the two cues were stored differently in memory, they would show contrasting retention characteristics for the rehearsal and interpolated activity conditions. This prediction was not supported as the interactions were not significant. Since differences between the two cues were found for the main effects, it appears that active movement cues are more exactly represented in memory than passive movement cues and are more capable of being used for movement reproduction.

It is evident for direction and distance movement cues that a change in the angle at which a movement is made effects both the error detection process and the memory trace process. To investigate whether active and passive movement cues are similarly influenced, the Movement Set by Angle of Movement Interactions were examined. It was found that the memory trace processes for the two sets of cues are different since the Active Movement Group produced more accurate movement reproductions for both direction and extent conditions. Active and passive movement cues are not as distinctly contrasted with respect to the error detection process. The only significant difference was the more sensitive detection process under the direction condition set by the Active Movement Group.

Models

One of the purposes of this study was to test the predictions made by two recent models of MSTM (Pepper & Herman, 1970; Laabs, 1973). A two process assimilation model is proposed by Pepper & Herman (1970); one process involving a change over time in the memory trace (spontaneous decay) and the second being an alteration in the memory trace arising either from general changes in the level of muscle tension or from additional specific motor acts (interference). The two processes are considered to occur within a single mode of memory.

The present findings are in conflict with the predictions of the assimilation model in that the cues manipulated in this study did not display spontaneous forgetting. The contention by Pepper & Herman (1970) that interpolated activity will produce forgetting received some support in the present study, random movement resulting in a decrease in the accuracy of movement direction reproduction. However, the retention of distance movement cues was not appreciably altered indicating that only certain cues are subject to the interference processes. In addition, the concept that a general change in muscle tension would influence retention - as should have been experienced by S in the CB condition of this study - was not supported, there being no increase in forgetting of the cues employed for the CB condition over that for IR.

Laabs (1973) proposes a model that calls for two modes of storage in MSTM. One mode uses a kinesthetic memory code which is subject to spontaneous forgetting and the other mode uses a central memory code which is subject to forgetting when rehearsal is blocked. He further postulates that distance cues are stored in the kinesthetic memory mode and location cues in the central memory mode.

The present interpretation in respect to distance and direction cues were in direct opposition to the two memory modes hypothesized by Laabs (1973). Distance cues should have been stored in the kinesthetic memory mode and should have exhibited spontaneous forgetting in the MR condition.

This suggests that distance cues have access to the central processing capacity. Direction cues were centrally represented and followed the predictions made by Laabs (1973) for movement cues that are rehearsable. MR maintained the accuracy of the memory trace to a degree comparable to that of IR while interpolated activity, that inhibited rehearsal, resulted in an increase in forgetting.

Marteniuk (1973), although not interpreting his results in the form of a model indirectly offered an alternative approach to the assimilation (Pepper & Herman, 1970) and adaptation (Laabs, 1973) models. It is suggested that there is a single mode of memory in MSTM since the cues examined - distance, location, active and passive movement cues - were all found to have access to the central processing capacity. These different cues were hypothesized to be initially represented in memory in varying degrees of exactness this being particularly evident with respect to location cues over distance cues and less apparent for active movement cues over passive movement cues. Finally, Marteniuk contends that these cues will show no retention loss except when a secondary task is interpolated in the retention interval.

The findings of the present study generally support the explanations proposed by Marteniuk (1973) . The cues manipulated appeared to be centrally represented in memory since they exhibited no spontaneous forgetting over time.

Direction cues and Active movement cues also seemed to be initially represented in memory more exactly than distance cues and Passive movement cues. The present results are in conflict with the predictions of Marteniuk concerning the interference of a secondary task. Interpolated RD and CB resulted in a retention loss for direction cues but not for distance cues. Moreover, the retention interval conditions failed to differentiate between Active movement cues and Passive movement cues.

Criticism of present models is certainly beneficial but it only provides half of the picture. The next step is to provide a plausible alternative, which will be the concern of the remainder of this discussion. One of the major implications of the present paper is that MSTM should be examined in terms of error detection processes and memory trace processes. This calls for the use of four error measurements. $\overline{CE}$ and VE are indicies of the error detection mechanism, with $\overline{CE}$ as the appropriate measure of the relationship between the criterion movement and the error detection level selected by S. VE is an index of the sensitivity of the detection process. It is proposed that when S makes a reproduction movement he has a detection level formulated which constitutes the amount of error he will tolerate and still consider the reproduction accurate. This detection level may fluctuate among reproductions, the amount of variation being a function of the sensitivity of the detection mechanism.

The error detection process is based upon the movement cues utilized for movement reproduction. S is more capable of employing direction, location and active movement cues for establishing an accurate and sensitive detection mechanism as compared to distance and passive movement cues. This may be attributable to the fact that direction information is readily available via stimulation of kinesthetic sense organs whereas distance information can only be derived from a higher order synthesis of information. Similarily, active movement cues contain an efferent copy of the motor program unlike passive movement cues, thus providing more information upon which S can operate his error detection mechanism (Marteniuk & Roy, 1972b). Therefore, it can be predicted that when movement reproductions are being made for a cue such as location, $\overline{CE}$ and VE will be close to zero. In contrast, if distance movement reproductions are being made, a high $\overline{CE}$ and VE will be observed.

The error detection mechanism is set by S and as such should be influenced by various factors including a secondary task and the angle of movement. As predicted, the angle at which a movement was made consistently produced a change in the error detection process. In the present study, S did not alter his error detection values of distance reproduction for the various retention interval conditions. This was probably due to S not being able to form a very accurate error detection level or sensitive detection value for distance cues in the IR condition. Therefore, interpolated activity was not able to appreciably alter the error detection values formulated by S from those utilized for IR. Although not investigated in this experiment, KR would also be expected to produce changes in the error detection values selected by S.

The memory trace process is indexed by $\overline{AE}$, the accuracy with which S reproduces the criterion movement, and AV, the strength of the memory trace. It is proposed that movement cues are encoded and stored in a central memory mode, but with varying degrees of exactness and precision. Direction, location and active movement cues are initially more exactly and precisely represented in memory than distance and passive movement cues. As a result, when S is making a reproduction based on a cue such as location, a low $\overline{AE}$ and AV will be observed. When S reproduces movement distance, a high $\overline{AE}$ and AV will be observed.

Since movement cues have access to the central processing capacity, they are subject to interference from an interpolated task in that it will inhibit rehearsal. This interference may be similar to the concept of the adaptation level or referent movement as proposed by Laabs (1973). As a result of interference, a reproduction is made in reference to an "average" value in addition to the given memory trace. Consequently, there will be an assimilation toward the central angle when the direction cue is used. Thus with interpolated activity, $\overline{AE}$ is expected to increase. Rehearsal, of an item in memory is assumed to act in direct opposition to interference. No change or a decrease in the emphasis placed on the referent movement in determining the response will result.

The explanation for an increase in AV with interference involves the notion of consistency in reproduction which is represented by the dispersion of reproductions of the same category of CM. As the memory trace of a movement is changed due to interference, not only will assimilation to the referent movement occur, but also the dispersion of reproductions may spread out. In other words, S has to base his reproductions on a weakened memory trace. Rehearsal can have the opposite effect of strengthening the memory trace so that S becomes more consistent in his reproductions.

Contrary to the predictions of this model, the accuracy of distance reproduction and the strength of the memory trace were not altered when rehearsal was blocked by a secondary task. Furthermore, rehearsal also failed to influence the memory trace process for distance cues. A probable explanation for this deviation from the predicted events follows the same reasoning given for the failure of the retention interval conditions to alter the error detection process employed by S for distance cues. The reproduction of distance cues was very inaccurate and the memory trace for movement distance relatively weak for immediate reproduction. Therefore, interpolated activity could not be expected to have any further influence on the memory trace process, since only minimal rehearsal of the cue would be required to maintain the initial intensity of the memory trace.

One final concept of the model concerns the relationship the error detection process and the memory trace process. Generally, when S changes his error detection level for movement reproduction and/or the sensitivity of that detection process, there usually will be an accompanying change in the accuracy of reproduction and/or the strength of the memory trace. A case in point would be if S shifted from movement distance reproduction to movement location reproduction. He would initially set a new error detection level for movement reproduction that more closely approximated the criterion movement value. He would also become more consistant in the utilization of this detection level over numerous trials. Since S has now decreased the error which he will tolerate when comparing a reproduction movement to the criterion movement, the accuracy with which he makes his movement reproductions will probably increase. Moreover, he should also become more consistent in his reproductions. As a rule, therefore, a positive change in the error detection process will be accompanied by a positive change in the memory trace process. Conversely, a negative change in the error detection process will probably be complimented by a negative change in the memory trace process.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

This study was conducted to examine the retention characteristics of direction, distance, active, and passive movement reproduction cues and the results were discussed in terms of the processes that occur in KSTM. The error detection process was indexed by $\overline{CE}$ and VE. S forms an error detection level for reproducing a movement that operates similar to a servo mechanism. This predetermined error detection level selected by S is measured by $\overline{CE}$; how close S sets the detection level to the criterion movement value. VE is a measure of the sensitivity of the error detection process S employs.

$\overline{AE}$ was considered an index of the memory trace accuracy. It is a measure of how accurately S can reproduce the criterion movement employing the error detection level he has set. As such, $\overline{AE}$ is a measure of forgetting. AV is the variability of the movement reproduction accuracy shown by S, or more simply, the strength of the memory trace. Thus $\overline{AE}$ and AV provided information concerning the state of the memory trace in the present study.

The present research has illustrated that $\overline{CE}$ - VE and $\overline{AE}$ - AV can meaningfully be used to interpret data on movement cues. When only one distribution of error scores ($\overline{CE}$ and VE or $\overline{AE}$ and AV) are examined, conflicting interpretations are produced and confusion is created in the KSTM literature.

The processes of MSTM as indexed by the four error terms were examined over the conditions of Movement Set, Retention Interval, and Angle of Movement. The Ss were 80 male students from Forster Secondary School, Windsor. Each subject was tested under all levels of Angle of Movement but only under one Movement Set and Retention Interval.

Conclusions

In terms of the hypotheses formulated, the following conclusions were formulated.

1. Active movement cues are more exactly represented in memory than passive movement cues since they are more capable of being used for movement reproduction.
2. Distance movement cues and direction movement cues both have access to the central processing capacity, however distance movement cues are not as exactly represented in memory as direction cues. The retention of distance movement cues is not enhanced by mental rehearsal or inhibited by interpolated activity as is the retention of direction movement cues.
3. The angle of a movement influences the reproduction of

direction and distance movement cues; at 90° the reproduction of these cues is significantly better than at 45° and 135°, between which there is minimum appreciable difference.

4. Active and passive movement cues are not differentiated by the retention interval conditions of IR, MR, RD, and C.
5. Active and passive movement cues are differentiated by the angle of movement, Active movement cues being more accurately reproduced than Passive movement cues at 90°. This difference is less evident at 45° and 135°.

With respect to the processes involved in MSTM, the error detection process for direction cues was effected by all three of the independent variables employed in the study - Movcment Set, Retention Interval, and Angle of Movement. The memory trace process was similarly influenced with the exception that the strength of the memory trace did not vary with the angle of the movement. For distance cues, the error detection process was altered by the Movement Set and Angle of Movement conditions but not the Retention Interval conditions. The error detection level and the sensitivity of the detection process did not change with the opportunity for rehearsal or the interference of a secondary task because distance cues are not readily used in the detection process. The memory trace process demonstrated changes over the conditions examined that corresponded to the changes of the error detection process.

The corresponding trends in the two processes for the conditions investigated indicates that a change in the memory trace is relatively predictable from a change in the error detection. This is logical since the less the error tolerance as determined by the criterion level and the more sensitive the error detection process, the more accurate and stronger the memory trace should be.

This research indicates that timing is not employed by S as a cue upon which movement reproductions are based. S concentrated on cues inherent in the movement when making a reproduction rather than formulating cues based on extrinsic factors such as counting.

Finally, a model of KSTM was proposed to explain the results of this research. It is proposed that movement cues are coded and stored in a central memory mode and movement reproductions are based upon the memory trace of the movement cue and the error detection mechanism which monitors the kinesthetic feedback from the reproduced movement. Movement cues all have access to the central processing capacity being subject to interference and rehearsal effects, but are represented in memory in varying degrees of exactness and precision. Direction, location, and active movement cues are initially more exactly and precisely represented in memory than distance and passive movement cues. The error detection process is based upon the movement cues utilized for movement reproduction. Direction, location, and active movement cues are more capable of being employed for establishing an accurate and sensitive detection process compared to distance and passive movement cues.

Further Direction

It was evident from the results of the study that movement cue research is still in the initial development stage and much work must be undertaken before a complete understanding of KSTM is achieved. Other movement cues that should be examined include acceleration, deceleration, and rate of movement. The retention characteristics of movement cues may also be investigated following the approach taken by MSTM researchers. PI and RI paradigms can be constructed examining factors such as the number of repetitions of the criterion movement and similarity of movements.

The analysis and interpretation of results pointed out the importance of using four error terms for investigating movement cue research. It is necessary that future research also employ $\overline{AE}$, AV, $\overline{CE}$, and VE in order to confirm the interpretations formulated in the present study and standardize the analysis of KSTM experiments.

APPENDIX A

INSTRUCTIONS

INSTRUCTIONS

The following instructions were read to each subject.

1. Imagine the area directly before you to be a half circle.
2. Imagine this half circle to be divided by three straight lines, coming from the centre of the baseline, into 4 equal sizes.
3. Direction No. 1 will be the line on your right, direction No. 2 will be the middle line, and direction No. 3 will be the line on your left.
4. The task is to draw (or I will move you) a straight 4" line along either direction No. 1, No. 2, or No. 3. Draw the line slowly.
5. When you have drawn the 4" line, stop, but keep your hand on the apparatus.
6. Immediate Reproduction: Having completed what you believe to be a 4" line, I will wait one second and then touch your hand. This is the signal to continue to make your line in the same direction as the first line. You are also to make it the same length as the first line.

Mental Rehearsal: Having completed what you believe to be a 4" line, continue to hold the handle and think about the length and direction of the line you just made. At the end of 10 seconds I will touch your hand. Then I want you to make a line in the same direction and the same length as the first line.

Random Movement: Having completed what you believe to be a 4" line, I want you to continue to hold the apparatus while I move you randomly. At the end of 10 seconds I will return you to the end-point of the line you made. I will then touch your hand and I want you to make a line in the same direction and the same length as the first line.

Counting: Having completed what you believe to be a 4" line, I will give you a number. I want you to repeat that number (still holding on to the handle) and count backwards out loud by threes. At the sound of the buzzer terminate the counting. I will then touch your hand and I want you to make a line in the same direction and the same length as the first line.

7. When you have completed the second line remove your hand from the apparatus, put it on your other hand, and wait for the next request.
8. There will be a 30 second time interval between trials.
9. Put the blindfold on and then the earphones.

S was then shown the baseline of the half circele by E passively moving S along the 0° baseline and then the 180° baseline. This procedure was done twice. These movements were four inches long. E then asked S if there were any questions regarding the above procedure. When these questions were answered, the testing commenced with the signal to start a given trial being the increase in the intensity of the random noise. During the ITI the intensity of the noise was halved to avoid discomfort to S and so it could be increased to signal the start of the next trial.

APPENDIX B

DATA TABLES

TABLE I

ANALYSIS OF VARIANCE OF THE MAIN EFFECTS AND INTERACTIONS

FOR THE $\overline{CE}$ OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	3675.4045	79			
A	93.5270	1	93.5270	2.06	0.1555
B	298.9128	3	99.6376	2.19	0.0961
AB	13.1507	3	4.3536	0.10	0.9616
SUBJ W GROUP	3269.8140	72	45.4141		
WITHIN SUBJ	8428.0703	160			
C	2341.1553	2	1170.5781	33.52	0.0000
AC	142.1739	2	71.0869	2.04	0.1344
BC	776.9065	6	129.4844	3.71	0.0019
ABC	138.5778	6	23.0963	0.66	0.6808
C X SUBJ W G	5029.9250	144	34.9253		

TABLE II

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE VE OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	1322.1094	79			
A	.4375	1	256.4375	20.32	0.0000
B	121.8242	3	40.6080	3.22	0.0277
AB	350.3516	3	11.6784	0.93	0.4330
SUBJ W GROUP	908.8125	72	12.6223		
WITHIN SUBJ	908.4921	160			
C	14.4648	2	7.2324	1.30	0.2767
AC	45.6133	2	22.8066	4.09	0.0188
BC	25.8945	6	4.3158	0.77	0.5919
ABC	19.0273	6	3.1712	0.57	0.7548
C X SUBJ W G.	803.4921	144	5.5798		

TABLE III

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE $\overline{AE}$ OF DIRECTION

SOURCE	SS	df	MS	F	P
BET SUBJ	2452.2305	79			
A	631.2813	1	631.2813	36.17	0.0000
B	453.3242	3	151.1081	8.66	0.0001
AB	110.8281	3	36.9427	2.12	0.1056
SUBJ W GROUP	1256.7969	72	17.4555		
WITHIN SUBJ	2184.3477	160			
C	205.8125	2	102.9062	9.29	0.0002
AC	78.3203	2	39.1601	3.53	0.0317
BC	202.0313	6	33.6719	3.04	0.0079
ABC	102.5039	6	17.0840	1.54	0.1686
C X SUBJ W G	1595.6797	144	11.0811		

TABLE IV

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE AV OF DIRECTION

Source	SS	df	MS	F	P
BET SUBJ	656.2109	79			
A	111.7695	1	111.7695	19.45	0.0003
B	100.3633	3	33.4544	5.82	0.0013
AB	30.2852	3	10.0951	1.75	0.1631
SUBJ W GROUP	413.7930	72	5.7471		
WITHIN SUBJ	726.1445	160			
C	21.2695	2	10.6348	2.42	0.0929
AC	18.6523	2	9.3262	2.12	0.1238
BC	34.4766	6	5.7461	1.31	0.2584
ABC	178.8398	6	2.9733	0.68	0.6695
C X SUBJ W G	633.9063	144	4.4021		

TABLE V

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE $\overline{CE}$ OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	867.9148	79			
A	137.1946	1	137.1946	14.40	0.0003
B	28.3194	3	9.4398	0.99	0.4020
AB	16.5704	3	5.5235	0.58	0.6300
SUBJ W GROUP	685.8303	72	9.5254		
WITHIN SUBJ	381.6372	160			
C	67.1962	2	33.5981	16.39	0.0000
AC	2.8353	2	1.4177	0.69	0.5024
BC	9.5284	6	1.1588	0.77	0.5910
ABC	6.8282	6	1.1380	0.56	0.7653
C X SUBJ W G	295.2492	144	2.0503		

TABLE VI

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE VE OF EXTENT.

Source	SS	df	MS	F	P
BET SUBJ	59.8872	79			
A	4.2026	1	4.2026	6.41	0.0135
B	5.1680	3	1.7227	2.63	0.0566
AB	3.3328	3	1.1109	1.70	0.1756
SUBJ W GROUP	47.1838	72	0.6553		
WITHIN SUBJ	68.5315	160			
C	3.4104	2	1.7052	4.07	0.0191
AC	0.4712	2	0.2356	0.56	0.5712
BC	2.5347	6	0.4224	1.01	0.4225
ABC	1.7593	6	0.2932	0.70	0.6502
C X SUBJ W G	60.3560	144	0.4191		

TABLE VII

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE $\overline{AE}$ OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	207.0203	79			
A	1.6069	1	1.6069	0.63	0.4296
B	6.0647	3	2.0216	0.79	0.5014
AB	15.9277	3	5.3092	2.08	0.1098
SUBJ W GROUP	183.4209	72	2.5475		
WITHIN SUBJ	146.2356	160			
C	14.2134	2	7.1067	8.44	0.0003
AC	5.4316	2	2.7158	3.23	0.0425
BC	2.1116	6	0.3519	0.42	0.8658
ABC	3.2922	6	0.5487	0.65	0.6883
C X SUBJ W G	121.1867	144	0.8416		

TABLE VIII

ANALYSIS OF VARIANCE OF MAIN EFFECTS AND INTERACTIONS

FOR THE AV OF EXTENT

Source	SS	df	MS	F	P
BET SUBJ	78.2720	79			
A	0.4346	1	0.4346	0.44	0.5113
B	2.5564	3	0.8521	0.85	0.4688
AB	3.4526	3	1.1509	1.15	0.3334
SUBJ W GROUP	71.8284	72	0.9976		
WITHIN SUBJ	46.5906	160			
C	1.5955	2	0.7977	2.71	0.0697
AC	0.2239	2	0.1119	0.38	0.6842
BC	1.0315	6	0.1719	0.58	0.7423
ABC	1.3616	6	0.2269	0.77	0.5937
C X SUBJ W G	42.3782	144	0.2943		

TABLE IX

MEAN DIRECTION IN DEGREES OF THE MAIN EFFECTS FOR MOVEMENT SET, RETENTION INTERVAL AND ANGLE OF MOVEMENT

Main Effect	$\overline{AE}$	AV	$\overline{CE}$	VE
Movement Set				
Active Movement	16.33	10.45	3.49	13.69
Passive Movement	26.06	14.55	-0.25	19.90
Retention Interval				
Immediate Reproduction	20.60	10.77	-3.17	15.50
Mental Reproduction	14.99	10.67	0.64	14.07
Random Movement	26.32	15.36	5.97	19.55
Counting	22.87	13.22	3.05	18.07
Angle of Movement				
45°	7.29	4.05	4.60	5.44
90°	5.80	3.87	0.00	5.41
135°	8.00	4.57	-2.99	5.94

TABLE X

MEAN EXTENT IN CM. OF THE MAIN EFFECTS FOR MOVEMENT SET, RETENTION INTERVAL AND ANGLE OF MOVEMENT

Main Effect	$\overline{AE}$	AV	$\overline{CE}$	VE
Movement Set				
Active Movement	7.34	3.76	-4.51	4.30
Passive Movement	6.86	4.02	0.02	5.11
Retention Interval				
Immediate Reproduction	6.59	3.60	-1.60	4.83
Mental Rehearsal	7.14	3.95	-3.09	4.11
Random Movement	7.85	4.37	-0.90	5.33
Counting	6.82	3.64	-3.09	4.58
Angle of Movement				
45^{o}	2.37	1.35	-0.78	1.73
90^{o}	2.06	1.18	-0.08	1.44
135^{o}	2.66	1.35	-1.37	1.54

TABLE XI

$\overline{CE}$ AND VE OF THE MOVEMENT SET BY RETENTION INTERVAL INTERACTION

IN CM. FOR EXTENT

	Immediate		Mental		Random		Counting	
	$\overline{CE}$	VE	$\overline{CE}$	VE	$\overline{CE}$	VE	$\overline{CE}$	VE
Active Movement	-2.81	4.18	-6.19	4.32	-4.12	4.69	4.94	4.08
Passive Movement	-0.40	5.49	-0.59	3.91	2.32	5.97	1.24	5.08

TABLE XII

$\overline{CE}$ ANE VE OF THE MOVEMENT SET BY ANGLE OF MOVEMENT INTERACTION

IN CM. FOR EXTENT

	45°		90°		135°	
	$\overline{CE}$	VE	$\overline{CE}$	VE	$\overline{CE}$	VE
Active Movement	-1.64	1.53	-0.88	1.32	-1.98	1.45
Passive Movement	0.07	1.92	0.71	1.56	-0.77	1.63

TABLE XIII

$\overline{AE}$ AND AV OF THE MOVEMENT SET BY RETENTION INTERVAL INTERACTION IN CM. FOR EXTENT

	Immediate		Mental		Random		Counting	
	$\overline{AE}$	AV	$\overline{AE}$	AV	$\overline{AE}$	AV	$\overline{AE}$	AV
Active Movement	7.11	3.41	8.32	4.42	6.91	3.86	7.00	3.37
Passive Movement	6.02	3.79	5.96	3.50	8.80	4.88	6.65	3.39

TABLE XIV

$\overline{AE}$ AND AV OF THE MOVEMENT SET BY ANGLE OF MOVEMENT INTERACTION IN CM. FOR EXTENT

	45°		90°		135°	
	$\overline{AE}$	AV	$\overline{AE}$	AV	$\overline{AE}$	AV
Active Movement	2.40	1.27	1.99	1.14	2.95	1.34
Passive Movement	2.34	1.43	2.14	1.22	2.37	1.35

TABLE XV

$\overline{CE}$ AND VE OF THE MOVEMENT SET BY RETENTION INTERVAL INTERACTION IN DEGREES FOR DIRECTION

	Immediate		Mental		Random		Counting	
	$\overline{CE}$	VE	$\overline{CE}$	VE	$\overline{CE}$	VE	$\overline{CE}$	VE
Active Movement	-0.55	10.50	1.86	12.14	7.10	16.89	5.58	15.26
Passive Movement	-5.78	20.50	-0.57	16.01	4.84	22.21	0.52	20.88

TABLE XVI

$\overline{CE}$ AND VE OF THE MOVEMENT SET BY ANGLE OF MOVEMENT INTERACTION

IN DEGREES FOR DIRECTION

	45°		90°		135°	
	$\overline{CE}$	VE	$\overline{CE}$	VE	$\overline{CE}$	VE
Active Movement	4.14	5.01	1.13	3.96	-1.77	4.72
Passive Movement	5.06	5.87	-1.11	6.86	4.20	7.16

TABLE XVII

$\overline{AE}$ AND AV OF THE MOVEMENT SET BY RETENTION INTERVAL INTERACTION IN DEGREES FOR DIRECTION

	Immediate		Mental		Random		Counting	
	$\overline{AE}$	AV	$\overline{AE}$	AV	$\overline{AE}$	AV	$\overline{AE}$	AV
Active Movement	12.70	7.45	12.72	10.04	22.23	13.91	17.68	10.43
Passive Movement	28.50	14.09	17.27	11.29	30.42	16.82	28.07	16.01

TABLE XVIII

$\overline{AE}$ AND AV OF THE MOVEMENT SET BY ANGLE OF MOVEMENT INTERACTION

IN DEGREES FOR DIRECTION

	45^{o}		90^{o}		135^{o}	
	$\overline{AE}$	AV	$\overline{AE}$	AV	$\overline{AE}$	AV
Active Movement	6.50	3.74	4.10	2.88	5.72	3.83
Passive Movement	8.28	4.37	7.50	4.86	10.28	5.31

TABLE XIX

ANALYSIS OF VARIANCE FOR CRITERION

AND REPRODUCTION MOVEMENT TIMES AT 45°

Source	SS	df	MS	F	P
BET SUBJ	279.1435	79	3.5335		
WITHIN S.	45.1929	80	0.5649		
TREAT	7.4238	1	7.4238	15.53	0.0001
RESID	37.7669	79	0.4781		

TABLE XX

ANALYSIS OF VARIANCE FOR CRITERION

AND REPRODUCTION MOVEMENT TIMES AT 90°

Source	SS	df	MS	F	P
BET SUBJ	242.9562	79	3.0754		
WITHIN S	36.1042	80	0.4513		
TREAT	0.6140	1	0.6140	1.37	0.2459
RESID	35.4902	79	0.4492		

TABLE XXI

ANALYSIS OF VARIANCE FOR CRITERION

AND REPRODUCTION MOVEMENT TIMES AT 135°

Source	SS	df	MS	F	P
BET SUBJ	250.4270	79	3.1700		
WITHIN S	43.6646	80	0.5458		
TREAT	0.8328	1	0.8328	1.54	0.2189
RESID	42.8300	79	0.5422		

APPENDIX C

CORRELATION TABLES

TABLE XXII

COEFFICIENT OF CORRELATION FOR DIRECTION
AT ANGLES FOR $\overline{CE}$, VE, AND $\overline{AE}$

	VE 45°	VE 90°	VE 135°	$\overline{AE}$ 45°	$\overline{AE}$ 90°	$\overline{AE}$ 135°
$\overline{CE}$ 45°	0.0887	0.1799	0.1436	0.7875	0.1015	0.2115
$\overline{CE}$ 90°	-0.1391	-0.1591	-0.0751	0.0878	-0.4091	-0.1873
$\overline{CE}$ 135°	-0.0163	-0.0355	-0.1170	-0.1929	-0.1165	-0.4208
VE 45°		0.1890	0.5268	0.4579	0.1369	0.3188
VE 90°			0.4710	0.2865	0.7369	0.4160
VE 135°				0.3355	0.4019	0.5808

TABLE XXIII

COEFFICIENT OF CORRELATION FOR EXTENT AT ANGLES FOR $\overline{CE}$, VE, AND $\overline{AE}$

	VE			$\overline{AE}$		
	45°	90°	135°	45°	90°	135°
$\overline{CE}$ 45°	0.1226	0.1333	0.0252	-0.2472	0.1537	-0.2884
$\overline{CE}$ 90°	0.1257	0.1345	0.0007	-0.1696	0.0799	-0.3601
$\overline{CE}$ 135°	0.1114	0.0351	-0.0963	-0.1842	0.0667	-0.5840
VE 45°		0.1339	0.3347	0.3617	0.1458	0.0481
VE 90°			0.1808	0.3310	0.4961	0.1305
VE 135°				0.3842	0.3471	0.4960

APPENDIX D

EXPERIMENTAL DATA

```
PASSIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

+ 8.1667-  .3333+ 3.6667 7.644911.294010.0609 8.1667 9.000010.3333      2204DIR
- 7.6667- 6.1667- 1.0000 5.7639 6.6937 5.8310 8.0000 8.1667 5.3333      2212DIR
+  .0000+ 1.6667-  .6667 3.1623 3.1972 6.3937 4.3333 3.0000 5.8333      2220DIR
+ 1.5000- 8.6667- 5.5000 8.0364 9.5161 6.5000 5.1667 9.3333 7.1667      2228DIR
- 2.1667+ 7.8333- 3.0000 1.343711.0366 7.3030 2.166710.1667 7.6667      2236DIR
+ 1.0000+ 1.5000+ 4.8333 2.1602 6.1033 3.9756 2.6667 4.8333 5.1667      2244DIR
- 3.1667+  .1667- 5.666712.0197 5.3671 6.472211.8333 4.5000 6.0000      2252DIR
+ 5.3333- 1.0000+  .5000 3.9441 2.0000 2.8723 5.3333 3.3333 2.5000      2260DIR
+ 8.1667+ 1.0000-10.0000 3.1314 5.5377 2.9439 8.1667 4.666710.0000      2268DIR
+ 2.1667+ 2.8333+ 1.6667 6.5680 3.3042 9.1043 6.5000 4.5000 8.8333      2276DIR
```

```
PASSIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-18 = AV.
(3F7.0)
7.6249 6.8313 2.8087 1.3270  .9123 1.4408      2204DIR
8.0000 8.1667 5.3333 3.0833 2.6500 5.3500      2212DIR
1.6957 2.0000 3.2672  .9195  .8597  .3145      2220DIR
2.6937 8.8632 4.5977 1.2522 1.7046 1.0415      2228DIR
1.3437 8.9334 1.8856 2.0669 1.2825  .6039      2136DIR
 .4714 4.0173 3.5316 1.0178  .3399  .4193      2244DIR
3.8042 2.9217 6.1644 1.9508  .5852  .5145      2252DIR
3.9441 1.4907 1.5000  .9679  .7668  .9274      2260DIR
8.1667 3.1147 2.9439 1.0044  .9263  .6599      2268DIR
2.3629 1.5000 5.1854  .6946 1.3933  .5354      2276DIR
```

```
PASSIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

+17.0000- 3.6667-20.0000 6.0277 9.7923 6.976117.0000 9.333320.0000      2306DIR
+15.2000+ 7.3333- 7.1667 4.490010.0775 5.636915.2000 9.3333 7.1667      2314DIR
+ 9.3333- 1.1667+ 3.0000 2.9674 3.8042 5.7735 8.3333 3.5000 4.3333      2322DIR
+27.1667- 5.1667-10.1667 8.896016.486515.049027.166716.166715.1667      2330DIR
+ 8.5000- 2.3333-15.500011.6010 5.022214.705412.8333 3.333317.5000      2338DIR
+ 3.1667- 5.1667- 7.3333 3.0777 6.1757 5.6766 4.1667 7.666710.6667      2346DIR
+ 3.0000- 4.0000+ 6.5000 3.1091 5.2599 4.7170 3.3333 5.6667 3.5000      2354DIR
+ 5.6667+ 6.5000- 3.5000 5.1208 5.5603 9.0975 6.0000 6.5000 8.1667      2362DIR
+12.0000- 8.6667- 2.8333 5.0662 3.7712 2.773812.0000 8.6667 3.1667      2370DIR
+ 4.3333+10.5000+12.833313.5113 6.652115.203312.000010.500015.8333      2378DIR
```

```
PASSIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-18 = AV
(3F7.0)

6.0277 4.7140 6.9761 1.1261 1.2226 1.5130      2306DIR
4.4900 8.2597 5.6356 1.4387 1.1160 1.1870      2314DIR
```

```
2.0495 1.8634 2.5658 2.3505 2.0936  .7128                  1203DIR
7.1667 1.6667 8.3333 3.7000 2.2500 3.4833                  1211DIR
3.9896 2.3629 1.3744  .5674 1.4369  .8280                  1219DIR
2.0344 1.9770 3.3541 1.0066 1.8726 2.0429                  1227DIR
2.2852 4.5513 4.9554 1.1676 2.0039 2.5799                  1235DIR
2.9297 3.9756 2.6087 1.0156  .4810 2.4409                  1243DIR
3.4480 4.2295 3.2469 1.6266 1.2557  .6866                  1251DIR
4.9805 3.2146 3.7156  .3304  .9813  .7824                  1259DIR
1.3944 1.9508 3.9016  .4958  .9634  .5715                  1267DIR
1.7078 3.2489 5.3437 1.4052 1.4021 1.3434                  1275DIR
```

ACTIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
+11.8333+ 3.6667+ 2.6667 7.0809 5.1854 6.944211.9333 5.0009 5.0000      1305DIR
+ 5.1667+ 5.0000- 4.3333 5.3781 5.5976 2.2111 5.1667 5.6667 4.3333      1313DIR
+ 7.0000+  .6667-  .6667 8.6987 5.4671 5.8214 8.0000 4.6567 5.0000      1321DIR
+ 9.5000+  .8333- 9.6667 7.5443 5.0139 9.768610.1667 4.166710.3333      1329DIR
+11.0000- 6.3333-10.1667 2.1602 6.4722 4.913111.0000 6.333310.1667      1337DIR
+ 4.0000+ 4.5000-14.3333 4.3205 1.1180 9.9007 5.6667 4.500014.3333      1345DIR
+11.3333+ 1.3333+  .8333 6.5490 4.2687 3.023011.3333 4.0000 2.5000      1353DIR
+  .1667- 1.0000- 8.0000 6.2561 4.8990 5.5976 5.1667 4.6667 8.0000      1361DIR
+11.6667+ 8.0000- 1.1667 5.7349 4.0415 6.792611.6667 3.0000 5.5000      1369DIR
+ 9.0000+ 5.3333+13.1667 7.1880 6.7495 6.175710.6667 6.333313.1667      1377DIR
```

ACTIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-18 = AV
(3F7.0)

```
7.0809 3.9158 5.5076 1.9905 1.0985  .3701                  1305DIR
5.3781 4.9216 2.2111  .7203  .3287 1.1557                  1313DIR
7.7889 2.9250 5.0551  .9012 1.9551  .5490                  1321DIR
6.6186 2.9107 7.5722 1.3515  .7358  .9339                  1329DIR
2.1602 6.4722 4.9131 1.3586 1.3392 2.0320                  1337DIR
1.5986 1.1180 8.9007 2.6930 1.1102 2.0538                  1345DIR
6.5490 2.1000 1.8930  .7290  .3716  .9703                  1353DIR
3.5316 1.7951 5.5976 1.8623 2.7500 2.9931                  1361DIR
5.7349 4.0415 4.1533 1.6527 1.4599 1.0227                  1369DIR
4.3461 5.8214 6.1757  .8896  .2134  .9452                  1377DIR
```

ACTIVE MOVEMENT - COUNTING
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
+ 5.1667- 1.0000- 5.8333 6.3900 3.5590 6.3618 6.5000 2.6667 8.1667      1407DIR
+  .3333- 3.6667+  .1667 3.3500 3.3152 6.7433 3.0000 4.3333 6.1667      1415DIR
+ 8.1667+  .1667+ 9.5000 9.1101 5.459410.0789 8.8333 4.500011.1667      1423DIR
+ 5.1667- 2.0000+ 3.6667 3.9756 5.5076 3.3993 5.5000 5.3333 4.6667      1431DIR
+ 7.0000+ 4.1667- 5.0000 4.2817 5.9713 4.9329 7.0000 5.3333 6.6667      1439DIR
```

```
+ 4.5000+ 1.8333-  .6667 3.4034 1.2134 7.4536 4.8333 1.9333 6.6667      1447DIR
- 5.3333+ 2.6667+  .8333 7.1336 1.8856 4.5246 5.5000 2.6667 3.8333      1455DIR
+ 6.3333+ 1.3333- 5.666710.1926 4.5338 1.490711.0000 3.6667 5.6667      1463DIR
+ 1.6667+ 3.6667- 3.3333 9.0077 2.5604 4.4597 6.8333 3.6667 3.3333      1471DIR
+18.0000+ 5.1667- 1.1667 2.5820 5.4594 3.387118.0000 5.8333 3.1667      1479DIR
```

ACTIVE MOVEMENT - COUNTING
COLUMNS 1-18 = AV
(3F7.0)

```
5.6495 2.5604 2.7938 1.2720  .3673 2.8059      1407DIR
1.5275 3.0368 2.7335 1.1225  .4525 1.2078      1415DIR
8.4738 3.0960 8.1938 1.5213  .6429  .8138      1423DIR
3.5000 2.4267 1.7951 1.0842  .6498  .8200      1431DIR
4.2817 4.2197 2.2111  .9214  .4534  .6549      1439DIR
2.9107 1.2134 3.3953 1.2543  .8133 2.1273      1447DIR
4.5735 1.9856 2.5441 1.6018 1.8850 2.0828      1455DIR
4.7958 2.9814 1.4907  .3057 1.8427  .6238      1463DIR
5.9838 2.5604 4.4597  .5708  .7515 1.1305      1471DIR
2.5820 4.7405 1.6750 1.4333  .7335  .3933      1479DIR
```

PASSIVE MOVEMENT - IMMEDIATE REPRODUCTION
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
- 4.1666-21.3333-13.8333 5.4899 2.6874 4.8103 4.833321.333313.8333      2102DIR
+ 1.3333-11.8333-15.8333 2.864714.5191 8.5521 1.333315.500015.8333      2110DIR
+ 8.3333- 3.8333-10.0000 2.5604 7.1278 6.0828 8.3333 6.833310.0000      2119DIR
+ 2.5000+ 4.1667+ 1.9333 5.708212.966810.4947 8.333312.1667 8.8333      2126DIR
+ 1.8333- 5.1667-12.0000 2.3393 3.3375 2.2361 2.5000 5.166712.0000      2134DIR
- 1.1667+ 3.6667+15.5000 4.7755 8.9194 3.6401 4.5000 7.000015.5000      2142DIR
- 1.0000+ 3.8333-11.166713.3041 6.0942 8.914711.6667 5.500013.5000      2150DIR
- 3.3333- 2.8333+14.5000 2.6874 8.0915 5.7951 3.3333 7.500014.5000      2158DIR
+ 2.5000- 1.6667- 5.3333 5.2836 2.7487 3.4480 5.1667 3.0000 5.3333      2166DIR
+ 6.6667- 5.1667+ 2.5000 2.6247 2.671910.5791 6.6667 5.1667 9.8333      2174DIR
```

PASSIVE MOVEMENT - IMMEDIATE REPRODUCTION
COLUMNS 1-18 = AV
(3F7.0)

```
4.9131 2.6974 4.8103  .9299  .4346 1.2628      2101DIR
1.696710.5159 8.5521  .5520 1.1657 1.2238      2110DIR
2.5604 4.3365 6.0828  .8576  .2864 1.5780      2118DIR
4.7405 6.1215 5.9555 1.0847 1.0463  .9639      2126DIR
1.6073 3.3375 2.2361 1.0399  .5620 1.4758      2134DIR
1.9791 6.6232 3.6401 1.5777  .7951  .4190      2142DIR
6.4722 4.6458 4.6815 1.4244 1.4395 1.4395      2150DIR
2.6874 4.1533 5.7951  .7362 1.2445 1.9146      2158DIR
2.7335 1.7951 3.4460 1.7075 1.6036 1.3082      2166DIR
2.6247 2.6719 4.6338 1.7459  .5558 1.5546      2174DIR
```

PASSIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
+ 8.1667-   .3333+ 3.6667 7.644911.294010.0609 8.1667 9.000010.3333      2204DIR
- 7.6667- 6.1667- 1.0000 5.7639 6.6937 5.8310 8.0000 6.1667 5.3333      2212DIR
+   .0000+ 1.6667-   .6667 3.1623 3.1972 6.3937 4.3333 3.0000 5.8333    2220DIR
+ 1.5000- 8.6667- 5.5000 8.0364 9.5161 6.5000 5.1667 9.3333 7.1667      2228DIR
- 2.1667+ 7.8333- 3.0000 1.343711.0366 7.3030 2.166710.1667 7.6667      2236DIR
+ 1.0000+ 1.5000+ 4.8333 2.1602 6.1033 3.9756 2.6667 4.8333 5.1667      2244DIR
- 3.1667+   .1667- 5.666712.0197 5.3671 6.472211.8333 4.5000 6.0000     2252DIR
+ 5.3333- 1.0000+   .5000 3.9441 2.0000 2.8723 5.3333 3.3333 2.5000     2260DIR
+ 8.1667+ 1.0000-10.0000 3.1314 5.5377 2.9439 8.1667 4.666710.0000     2268DIR
+ 2.1667+ 2.8333+ 1.6667 6.5680 3.3042 9.1043 6.5000 4.5000 8.8333      2276DIR
```

PASSIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-18 = AV.
(3F7.0)

```
7.6249 6.8313 2.8067 1.8270  .9123 1.4408      2204DIR
8.0000 8.1667 5.3333 3.0833 2.6500 5.3500      2212DIR
1.6957 2.0000 3.2672  .9195  .8597  .3145      2220DIR
2.6037 8.8632 4.5977 1.2522 1.7046 1.0415      2228DIR
1.3437 8.9334 1.8856 2.0669 1.2825  .6039      2136DIR
 .4714 4.0173 3.5316 1.7178  .3399  .4193      2244DIR
3.8042 2.9247 6.1644 1.9508  .5852  .5145      2252DIR
3.9441 1.4907 1.5000  .9679  .7668  .9274      2260DIR
8.1667 3.1147 2.9439 1.0044  .9263  .6599      2268DIR
2.3629 1.5000 5.1854  .6946 1.3933  .5354      2276DIR
```

PASSIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
+17.0000- 3.6667-20.0000 6.0277 9.7923 6.976117.0000 9.333320.0000       2306DIR
+15.2000+ 7.3333- 7.1667 4.490010.0775 5.636915.2000 9.3333 7.1667       2314DIR
+ 8.3333- 1.1667+ 3.0000 2.9674 3.8042 5.7735 8.3333 3.5000 4.3333       2322DIR
+27.1667- 5.1667-10.1667 8.896016.486515.049027.166716.166715.1667       2330DIR
+ 8.5000- 2.3333-15.500011.6010 5.022214.705412.8833 3.333317.5000       2338DIR
+ 3.1667- 5.1667- 7.3333 3.0777 6.1757 5.6766 4.1667 7.666710.6667       2346DIR
+ 3.0000- 4.0000+  .5000 3.1091 5.2599 4.7170 3.3333 5.6667 3.5000       2354DIR
+ 5.6667+ 6.5000- 3.5000 5.1209 5.5603 9.0875 6.0000 6.5000 8.1667       2362DIR
+12.0000- 8.6667- 2.8333 5.0662 3.7712 2.773812.0000 8.6567 3.1667       2370DIR
+ 4.3333+10.5000+12.833313.5113 6.652115.203312.000010.500015.8333       2378DIR
```

PASSIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-18 = AV
(3F7.0)

```
6.0277 4.7140 6.9761 1.1261 1.2226 1.5130      2306DIR
4.4900 8.2597 5.6396 1.4387 1.1160 1.1870      2314DIR
```

```
8.3333 1.8930 4.8534 1.1796 1.9746  .6218            2322DIR
8.8960 6.0942 9.9903 2.0399 2.5076 1.7861            2330DIR
6.4914 4.422212.2577 2.3521 2.0055 3.1774            2338DIR
1.4625 4.2590 3.9441  .8360 1.1547 1.1936            2346DIR
2.7487 3.3993 3.2016  .6562 1.3892 1.2499            2354DIR
1.4258 5.5603 5.3046 2.1669 2.1608 1.5137            2362DIR
5.0662 3.7712 2.4095 1.3422 2.4837 1.7201            2370DIR
7.5719 6.652112.0474 2.1440 1.8312 1.7075            2378DIR
```

PASSIVE MOVEMENT - COUNTING
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
- 4.5000-15.3333- 1.0000 6.925216.097814.1774 7.500016.160012.6667   2408DIR
-  .1667+ 1.3333-18.333311.0063 4.678611.2793 7.8833 4.000018.3333   2416DIR
+16.8333+ 3.3333- 8.5000 5.4898 3.9016 3.201616.8333 4.3333 8.5000   2424DIR
+12.1667+ 3.0000-14.3333 4.8791 2.8868 7.866912.1667 3.666714.3333   2432DIR
+ 4.3333+ 1.6667- 2.0000 4.1500 4.5613 4.9329 4.6667 4.5000 4.3333   2440DIR
+  .8333+ 2.1667- 6.8333 4.412711.5241 7.3352 3.1667 9.1667 7.1667   2448DIR
+12.5000- 2.0000-28.5000 5.8523 8.3066 6.601812.5000 7.333328.5000   2456DIR
+ 5.1667+ 3.6667- 3.3333 5.7539 5.497510.0609 5.1667 5.3333 9.0000   2464DIR
+14.0000- 3.6667+ 8.5000 9.6782 5.2175 6.344314.0000 5.3333 9.5000   2472DIR
+10.3333+ 9.0000+ 5.3333 3.5901 5.5076 3.144710.3333 9.0000 5.3333   2480DIR
```

PASSIVE MOVEMENT - COUNTING
COLUMNS 1-18 = AV
(3F7.0)

```
3.253215.7620 6.4464 2.4784 3.4411 2.8504   2408DIR
5.5603 2.768911.2793  .7522  .7381  .9360   2416DIR
5.4898 2.7487 3.2016 1.0292  .8981  .9123   2424DIR
4.8791 1.9720 7.8669 1.1856  .3399 1.2967   2432DIR
3.7712 1.3844 3.0912 2.0653  .3976  .4422   2440DIR
3.1842 7.3125 7.0099 1.5628  .7862 2.1258   2448DIR
5.8523 4.3843 6.6018 2.4274 1.4323 1.9729   2456DIR
5.0139 5.4975 5.5976  .3649 1.0058 2.1240   2464DIR
9.6782 3.4060 4.7170 1.8320  .6498  .4069   2472DIR
3.5901 5.5076 3.1447  .5416  .8711  .6149   2480DIR
```

EXTENT
ACTIVE MOVEMENT - IMMEDIATE REPRODUCTION
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
+ 2.3333+ 3.0000+ 2.3333 4.277 5..0662 3.5434 2.3333 4.0000 4.0000   1101EXT
- 1.2667+ 1.4833- 2.3833 1.4079  .8802  .5580 1.2667 1.4833 2.3833   1109EXT
+ 1.9500- 1.5500+ 1.9167 1.6060 1.7405 1.2980 1.8500 1.8500 1.9167   1117EXT
- 1.7500-  .9000- 3.5000 1.1221 1.0770  .7895 1.7833 1.1667 3.5000   1125EXT
- 3.1500- 1.2833+ 2.6833 1.1078 1.7696 1.9213 3.1500 1.3500 2.6833   1133EXT
- 2.3333-  .2000- 2.7000 1.0827  .8851 2.3615 2.3333  .2000 2.7000   1141EXT
- 1.7833- 1.8667- 3.2167 1.8827 1.4985  .9990 2.0167 1.8667 3.2167   1149EXT
```

-	1.8333-	2.4167-	5.1500	1.2899	.3474	.3995	2.0500	2.4167	5.1500	1157EXT
-	2.5333+	1.3333-	2.9000	1.0904	1.0419	.5196	2.5333	1.4667	2.9000	1165EXT
-	2.1000+	2.6167-	2.8333	.9000	1.5731	1.7346	2.1000	2.6167	2.8333	1173EXT

ACTIVE MOVEMENT -- IMMEDIATE REPRODUCTION
COLUMNS 1-18 = AV
(18X,3F7.0)

2.8674	4.3205	1.4142	.9713	.8707	1.6469	1101EXT
2.6719	1.9508	3.3166	.4749	.8802	.5580	1109EXT
2.7669	2.7538	1.9149	1.6060	1.4175	1.2780	1117EXT
.27437	1.4625	2.5820	1.0684	.7803	.7895	1125EXT
1.4907	1.6073	1.8930	1.1078	1.1644	1.9213	1133EXT
2.4095	1.5723	2.2361	1.0827	.6155	2.3615	1141EXT
3.2489	.8975	4.5246	1.6304	1.4985	.9990	1149EXT
4.5461	2.5604	7.3981	1.0029	.9474	.3995	1157EXT
1.6750	2.4395	2.3393	1.0904	.8439	.5196	1165EXT
1.0672	2.0817	2.7538	.9000	1.5731	1.7346	1173EXT

ACTIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

-	3.7167-	1.9667-	2.5833	3.2596	2.7538	.7128	4.4500	3.0000	2.5833	1203EXT
-	3.7000-	2.2500-	3.4833	1.4329	1.5692	2.0136	3.7000	2.2500	3.4833	1211EXT
-	1.4500+	1.4833-	1.8333	.5674	1.5399	.8280	1.4500	1.5833	1.8333	1219EXT
-	2.3000-	4.1000-	2.8000	1.0066	1.8726	2.0429	2.3000	4.1000	2.8000	1227EXT
-	2.3333-	2.5333-	4.6500	2.5688	2.0039	2.5799	2.3000	2.3333	4.6500	1235EXT
-	.7667+	.3833-	1.7333	1.5691	1.5115	1.0323	1.4000	1.4833	3.2000	1243EXT
+	3.3500-	2.4000+	2.5167	1.6266	1.2557	.6866	3.3500	2.4000	2.9167	1251EXT
-	1.8500-	2.7000-	3.3667	.3304	.8813	.7824	1.8500	2.7000	3.3667	1259EXT
-	1.7500-	.9833-	2.2000	.4958	1.0991	.5715	1.7500	1.1167	2.2000	1267EXT
-	4.4833-	4.4500-	3.6833	1.4052	1.4021	1.3434	4.4833	4.4500	3.6833	1275EXT

ACTIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-18 = AV
(18X,3F7.0)

2.0495	1.8634	2.5658	2.3505	2.0936	.7128	1203EXT
7.1667	1.6667	8.3333	3.7000	2.2500	3.4833	1211EXT
3.9896	2.3629	1.3744	.5674	1.4369	.8280	1219EXT
2.0344	1.9720	3.3541	1.0066	1.8726	2.0429	1227EXT
2.2852	4.5613	4.9554	1.1676	2.0039	2.5799	1235EXT
2.9297	3.9756	2.6087	1.0156	.4810	2.4409	1243EXT
3.4480	4.2295	3.2489	1.6266	1.2557	.6866	1251EXT
4.9805	3.2146	3.7156	.3304	.9813	.7824	1259EXT
1.3844	1.9508	3.9016	.4958	.9634	.5715	1267EXT
1.7078	3.2489	5.3437	1.4052	1.4021	1.3434	1275EXT

ACTIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

-	3.3000-	1.3667-	1.7167	2.2561	1.8273	1.6476	3.4667	2.0000	2.3333	1305EXT
-	.5500+	.0167-	1.0167	1.1325	.5843	1.9282	1.8167	.4833	1.8500	1313EXT
-	1.9333+	1.9667+	1.6833	.9012	1.9551	.5490	1.9333	1.9667	1.6833	1321EXT
-	2.1000+	.2833-	2.0500	1.3515	2.0334	1.5639	2.1000	1.9167	2.3833	1329EXT
-	2.0833-	2.5333-	5.2833	1.4588	1.6327	2.0820	2.1500	2.7000	5.2833	1337EXT
-	4.8500-	.8500-	4.5833	2.6930	1.3537	2.0538	4.8500	1.1500	4.5833	1345EXT
-	.7167-	.1500-	2.0167	.7290	.6185	.9703	.8833	.4628	2.0313	1353EXT
-	1.6333-	2.7500-	5.6333	2.7499	.7654	2.9831	2.6000	2.7500	5.6333	1361EXT
-	.8500+	1.2167-	1.3500	2.7729	2.0769	1.0227	2.3833	1.9167	1.3500	1369EXT
+	1.1500+	.0667+	1.7500	.9323	.5088	1.7793	1.1833	.9333	2.3500	1377EXT

ACTIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-18 = AV
(18X,3F7.0)

5.3781	4.9216	2.2111	.7203	.3287	1.1557	1313EXT
7.0809	3.9158	5.5076	1.9905	1.0985	.3731	1305EXT
7.7889	2.9250	5.0551	.9012	1.9551	.5490	1321EXT
6.6186	2.9107	7.9722	1.3515	.7359	.9339	1329EXT
2.1602	6.4722	4.9131	1.3586	1.3392	2.0820	1337EXT
1.5986	1.1180	8.9007	2.6930	1.1102	2.0538	1345EXT
6.5490	2.0000	1.8930	.7290	.3716	.9703	1353EXT
3.5316	1.7951	5.5976	1.8628	2.7500	2.9831	1361EXT
5.7349	4.0415	4.1533	1.6527	1.4599	1.0227	1369EXT
4.3461	5.8214	6.1757	.8896	.2134	.9452	1377EXT

ACTIVE MOVEMENT - COUNTING
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

-	5.7833-	2.6667-	5.8000	1.2720	.8673	2.8059	5.7833	2.6667	5.8000	1407EXT
+	1.0333+	.3833+	.0000	1.8526	1.2075	1.7263	1.8000	1.1833	1.2333	1415EXT
-	1.8167+	.4667-	.7333	2.4640	1.0934	1.1288	2.3833	1.0000	1.1667	1423EXT
+	1.4000+	.2667-	2.4333	1.2517	.7972	.8200	1.5333	.5333	2.4333	1431EXT
-	1.6667-	.6667-	.6667	.9214	1.2405	1.1264	1.6667	1.5667	1.1333	1439EXT
-	3.6000-	3.7167-	4.7833	1.2543	.8133	2.1273	3.6000	3.7167	4.7833	1447EXT
-	2.4500-	3.4000-	2.5167	1.6018	1.8850	2.3982	2.4500	3.4000	2.7833	1455EXT
-	1.4500-	3.1667-	2.6500	.8057	1.8427	.6238	1.4500	3.1667	2.6500	1463EXT
-	.9500-	.6500+	1.3166	1.2352	1.1786	1.3209	1.4500	1.1167	2.7500	1471EXT
-	2.1000+	1.1917-	1.7833	1.4333	1.3555	.3933	2.1000	.8833	1.7833	1479EXT

ACTIVE MOVEMENT - COUNTING
COLUMNS 1-18 = AV
(18X,3F7.0)

1.5275	3.0368	2.7335	1.1225	.4525	1.2078	1415EXT

```
5.6495 2.5604 2.7938 1.2720  .8673 2.8059                    1407EXT
8.4738 3.0960 8.1938 1.9213  .6429  .9138                    1423EXT
3.5000 2.4267 1.7951 1.0842  .6498  .8200                    1431EXT
4.2817 4.2197 2.2111  .9214  .4534  .6549                    1439EXT
2.9107 1.2134 3.3953 1.2543  .9133 2.1273                    1447EXT
4.5735 1.8856 2.5441 1.6018 1.8850 2.0328                    1455EXT
4.7958 2.9814 1.4907  .8057 1.8427  .6238                    1463EXT
5.9838 2.5604 4.4557  .5703  .7515 1.1305                    1471EXT
2.5820 4.7405 1.6750 1.4333  .7335  .3933                    1479EXT
```

PASSIVE MOVEMENT - IMMEDIATE REPRODUCTION
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
-   .4500+  .4000- 1.5167 1.3817  .8832 1.2628 1.1667  .8667 1.5167      2102EXT
+ 1.0333+ 2.3667+  .0000 1.0061 1.1657 1.9356 1.0667 2.3667 1.5000      2110EXT
+   .9333-  .1000-  .8667 1.9319  .9713 2.1515 1.9667  .9333 1.7000      2118EXT
+   .5000+  .6000-  .2166 1.2517 2.6571 1.7276  .8000 1.4833 1.4500      2126EXT
-   .2833-  .3833+ 2.8167 1.8730 1.1276 1.4758 1.5833 1.0500 2.8167      2134EXT
- 1.0833- 1.0000-  .0500 2.7961 1.5166 1.2764 2.4833 1.6333 1.1833      2142EXT
-   .4667-  .6333- 1.3667 2.5223 1.5326 1.4395 2.1333 1.4333 1.3667      2150EXT
-   .6167- 1.9000- 4.0333 2.7601 1.3441 2.3669 2.7167 1.9667 4.2667      2158EXT
+ 1.7667+ 1.3166- 1.3833 2.5940 1.8578 1.5181 2.6333 1.6167 1.5833      2166EXT
+ 2.4167+ 1.8333+ 2.3000 1.7459  .5558 1.5546 2.4167 1.8333 2.3000      2174EXT
```

PASSIVE MOVEMENT - IMMEDIATE REPRODUCTION
COLUMNS 1-18 = AV
(18X,3F7.0)

```
4.9131 2.6874 4.8103  .9299  .4346 1.2628                    2102EXT
1.696710.5159 8.5521  .5520 1.1657 1.2238                    2110EXT
2.5604 4.3365 6.0828  .8576  .2864 1.5780                    2118EXT
4.7405 6.1215 5.9559 1.0347 1.0463  .9639                    2126EXT
1.6073 3.3375 2.2361 1.0399  .5620 1.4758                    2134EXT
1.9791 6.6232 3.6401 1.5777  .7951  .4190                    2142EXT
6.4722 4.6458 4.6815 1.4244 1.4395 1.4395                    2150EXT
2.6974 4.1533 5.7951  .7862 1.2445 1.9146                    2158EXT
2.7335 1.7951 3.4480 1.7075 1.6036 1.3082                    2166EXT
2.6247 2.6719 4.6338 1.7459  .5558 1.5546                    2174EXT
```

PASSIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
(3F8.0,6F7.0)

```
- 1.3667+  .3667+  .4167 2.2697 2.1061 2.7248 1.8833 1.9333 2.3500      2204EXT
+ 3.0833- 1.8333- 5.3500 1.1021 2.8103 1.8963 3.0833 2.6500 5.3500      2212EXT
+ 1.0333+ 1.9833+  .4000 1.3888 1.1553 1.2423 1.4667 1.2500 1.2667      2220EXT
- 3.7167- 5.0333- 1.9167 1.2522 1.7046 1.1596 3.7167 5.0333 2.2500      2228EXT
- 3.1333- 1.2833- 1.5167 2.0669 1.2825 1.3184 3.1333 1.2833 1.9167      2236EXT
-   .6833+  .4667- 1.7500 3.3103  .3399  .4193 2.7833  .4667 1.7500      2244EXT
- 1.6667+  .7833-  .1500 2.4012  .7946 1.2816 2.3333  .9500 1.1833      2252EXT
```

+	.9667+	1.1167-	1.1000	1.5007	.7668	1.0440	1.5000	1.1167	1.2000	2260EXT
+	.0333+	2.6166+	2.3333	2.1784	.9263	.6599	1.9333	2.6166	2.3333	2268EXT
+	1.3500+	3.7833-	2.1000	.6946	1.3933	.5354	1.3500	3.7833	2.1000	2276EXT

PASSIVE MOVEMENT - MENTAL REHEARSAL
COLUMNS 1-18 = AV
(18X,3F7.0)

7.6249	6.0313	2.8087	1.3270	.9123	1.4408	2204EXT
8.0000	8.1667	5.3333	3.0833	2.6500	5.3500	2212EXT
1.6397	2.0000	3.2972	.7195	.8597	.3145	2220EXT
2.6087	8.8632	4.5977	1.2522	1.7046	1.0415	2228EXT
1.3437	8.9334	1.8856	2.0659	1.2825	.6039	2136EXT
.4714	4.0173	3.5316	1.0178	.3397	.4193	2244EXT
3.3042	2.9297	6.1644	1.5508	.5852	.5145	2252EXT
3.9441	1.4007	1.5000	.9678	.7668	.9274	2260EXT
8.1667	3.1167	2.9435	1.0044	.9263	.6590	2268EXT
2.3629	1.5000	5.1854	.6946	1.3933	.5354	2276EXT

PASSIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-24 = CS, 25-46 = VE, 47-54 = AL
(3F8.0,6F7.0)

-	2.7167+	.4167-	4.5500	1.1261	1.9565	1.5130	2.7167	1.5833	4.5500	2306EXT
+	.5333+	2.1333+	1.8000	1.5660	1.1160	1.8184	2.4000	2.1333	2.2667	2314EXT
+	.3833-	.4667-	.4000	2.6617	3.2045	.9309	2.4167	2.5667	.8000	2322EXT
+	3.0833+	3.0833+	3.7000	2.0399	2.5076	1.7861	3.0833	3.0833	3.7000	2330EXT
-	3.3500-	.7333-	6.3667	2.3521	2.9107	3.1774	3.3500	2.2333	6.3667	2338EXT
+	.7333+	3.6000+	.9333	1.4885	1.1547	2.0798	1.4333	3.6000	1.8667	2346EXT
-	.2500+	.3000-	2.3333	1.2633	1.8356	1.7471	3.6167	1.2000	2.6333	2354EXT
+	2.0333+	4.3333+	.9833	2.9629	2.1608	2.6767	5.3000	4.3333	2.4167	2362EXT
+	2.9833+	4.5666+	.6667	1.3422	2.4837	1.7201	2.9833	4.5666	2.0333	2370EXT
+	2.8667+	3.6000+	1.9000	2.5727	1.8312	1.7445	3.2000	3.6000	1.9333	2378EXT

PASSIVE MOVEMENT - RANDOM MOVEMENT
COLUMNS 1-18 = AV
(18X,3F7.0)

6.0277	4.7140	6.9761	1.1261	1.2226	1.5130	2306EXT
4.4900	8.2597	5.6396	1.4387	1.1160	1.1970	2314EXT
8.3333	1.8920	4.8534	1.1796	1.9746	.6218	2322EXT
8.8960	6.0942	9.9903	2.0399	2.5076	1.7861	2330EXT
6.4914	4.4922	12.2577	2.3521	2.0055	3.1774	2338EXT
1.4625	4.2596	3.9441	.3360	1.1547	1.1936	2346EXT
2.7497	3.3593	3.2016	.6962	1.3892	1.2499	2354EXT
1.4258	5.5603	5.3046	2.1669	2.1608	1.5137	2362EXT
5.0662	3.7712	2.4095	1.3422	2.4937	1.7201	2370EXT
7.5719	6.6521	12.0474	2.1440	1.8312	1.7075	2378EXT

```
                    PASSIVE MOVEMENT - COUNTING
          COLUMNS 1-24 = CE, 25-46 = VE, 47-68 = AE
                        (3F8.0,6F7.0)

+ 4.3667+ 7.1167+ 3.6833 2.4784 4.0251 2.8504 4.3667 7.4167 3.6833        2408EXT
+  .6833+  .1833+  .6667 1.3765 1.2980 1.2906 1.8500 1.0833 1.0667        2416EXT
-  .0500+  .3667- 3.4333 1.5425 1.4533  .9123 1.1500 1.2000 3.4333        2424EXT
- 1.3667+  .2333- 1.7500 1.1856  .4988 1.8401 1.3667  .4333 2.1833        2432EXT
- 1.5333+  .2833-  .2667 2.1077  .7600 1.0919 1.3367  .7167 1.0333        2440EXT
-  .6833+  .5500- 2.4333 2.4038 1.7896 2.3288 1.9500 1.5833 3.0667        2448EXT
- 1.6667- 2.7833- 4.1500 3.3663 1.4323 1.9729 2.8667 2.7833 4.1500        2456EXT
- 1.1833- 3.1167- 3.4167 1.7014 1.0058 2.4327 3.9833 3.1167 3.6167        2464EXT
-  .9167+  .2000-  .5000 2.0936  .7211  .4472 1.3500  .9333  .5333        2472EXT
-  .5000-  .4333-  .5833  .7303 1.3622 1.3309  .7000 1.1333 2.3833        2480EXT

                    PASSIVE MOVEMENT - COUNTING
                        COLUMNS 1-18 = AV
                          (13X,3F7.0)

3.253215.7630 6.4464 2.4784 3.4411 2.8504                                  2408EXT
5.5603 2.768911.2793  .7522  .7381  .9860                                  2416EXT
5.4898 2.7487 3.2016 1.0292  .8981  .9123                                  2424EXT
4.8791 1.9720 7.8669 1.1856  .3399 1.2967                                  2432EXT
3.7712 1.3644 3.0912 2.0653  .3976  .4422                                  2440EXT
3.1842 7.3125 7.0099 1.5628  .7862 2.1258                                  2448EXT
5.8523 4.3843 6.6018 2.4274 1.4323 1.9729                                  2456EXT
5.0139 5.4975 5.5976  .8649 1.0058 2.1240                                  2464EXT
9.6782 3.4960 4.7170 1.8320  .6498  .4069                                  2472EXT
3.5901 5.5076 3.1447  .5416  .8711  .6149                                  2480EXT

COL 73 IDENTIFIES ACTIVE MOVEMENT GROUP (NO. 1), PASSIVE MOVEMENT GROUP (NO. 2)
COL 74 IDENTIFIES IMMEDIATE REPRODUCTION (NO. 1), MENTAL REHEARSAL (NO. 2) ,
RANDOM MOVEMENT (NO. 3), AND COUNTING (NO. 4) COL 75-76 IDENTIFIES SUBJECT NO.
COL 77,78,79 IDENTIFIES MOVEMENT CUE- EXT = EXTENT, DIR = DIRECTION
                              MOVEMENT TIME
          SUBJECTS AGES - ANGLES OF MOVEMENT = 45,90,135 DEGREES
   COLUMNS 1-3=AGE (MONS),4-10=CM 45,11-16=CM 90,17-22=CM 135,23-28=RM 45,
                        29-34=RM 90,35-40=RM 135
                              (1F3.0,6F6.0)
1825.17435.81785.42183.91535.47844.2917                                   01TIM
2046.49425.98684.67406.18674.73014.5024                                   02TIM
2043.16503.13432.42622.65952.31252.2529                                   03TIM
2206.68878.06586.91037.10706.79556.1385                                   04TIM
1914.76874.14245.17503.78505.73863.5872                                   05TIM
1874.91245.29244.90704.07364.06404.1057                                   06TIM
1873.01922.30902.25632.34072.05962.2518                                   07TIM
1908.54675.67685.90136.33535.51475.0793                                   08TIM
2161.71881.70471.77431.40581.33251.7793                                   09TIM
1833.74394.46524.68573.73554.85964.2163                                   10TIM
2213.15072.81132.84752.32922.86252.1308                                   11TIM
1965.17835.27434.73134.58236.07425.2352                                   12TIM
1934.64263.79383.57253.28403.10653.2783                                   13TIM
2224.52706.06304.41554.97654.16374.1538                                   14TIM
2161.79023.04102.01381.68591.72631.5200                                   15TIM
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2045.47053.88334.16034.78023.71704.8335	16TIM
2182.02672.77981.97421.32031.62501.6023	17TIM
2134.05774.27144.14304.16383.83126.8657	18TIM
2033.39542.97552.90453.55883.04075.0273	19TIM
2154.30853.74434.13655.22624.52885.5573	20TIM
1912.37452.46822.71952.03082.01722.3708	21TIM
1955.97475.23635.21264.56004.29124.9734	22TIM
2285.05545.40506.38854.88325.81464.2828	23TIM
2035.04485.64684.50236.73134.34955.8952	24TIM
2113.53603.34684.17832.56702.27522.2865	25TIM
1864.72673.79653.92084.15684.95894.0467	26TIM
1913.06803.02533.09802.49022.72922.4220	27TIM
2034.07385.81263.75124.94453.66082.6347	28TIM
2061.68782.31652.19981.48981.61231.4898	29TIM
1994.75503.73804.16473.27692.78534.0803	30TIM
2252.87124.05303.75062.56563.16623.1193	31TIM
1704.86234.00805.01874.53873.89054.0115	32TIM
2401.90101.70601.82551.59171.52421.5797	33TIM
2095.65004.61353.76685.76275.91104.1538	34TIM
2038.82337.61079.09526.74307.57207.3333	35TIM
1714.82053.70183.69663.73652.56353.2896	36TIM
2064.24083.90073.71703.41223.12032.9982	37TIM
1905.86724.39304.18763.48884.01723.2584	38TIM
2225.00084.31734.14703.94483.48273.6885	39TIM
1844.07003.34323.80484.67605.30674.1275	40TIM
2333.61072.57922.69162.30122.17332.1240	41TIM
2124.57953.67273.18183.61653.83353.1557	42TIM
1974.78554.35474.87073.91534.93984.2192	43TIM
1913.30007.36963.69863.11573.94805.7870	44TIM
1804.20583.74684.34373.41133.51674.4900	45TIM
2064.19973.11773.26023.86033.36873.3125	46TIM
2221.68581.72331.52451.79023.02602.0405	47TIM
1554.12553.62724.27732.43732.62472.4952	48TIM
1703.31733.34073.13982.61073.13103.1567	49TIM
2184.46154.07784.26553.63133.23533.8672	50TIM
2141.73521.67751.44551.93231.60721.6238	51TIM
1874.44721.58755.20733.47603.35873.0282	52TIM
1872.82472.05552.42552.72751.75981.9880	53TIM
2294.02774.48443.15071.93422.31042.0100	54TIM
1805.29922.48704.24523.60334.12383.3937	55TIM
2103.89126.15353.92482.47132.60552.8907	56TIM
1972.35807.87572.19022.31032.49602.0393	57TIM
1834.07033.40273.94823.33333.05602.9703	58TIM
1933.42083.71752.88403.43383.10303.7788	59TIM
2143.83152.93524.56135.29134.15504.5648	60TIM
2011.98901.77201.82701.89671.90221.4087	61TIM
2054.82304.07504.28153.29494.87365.0677	62TIM
2103.45922.78303.24673.41563.69322.8842	63TIM
1804.30074.25204.25785.32306.44725.6812	64TIM
2062.14462.46072.32783.10762.45572.8212	65TIM
2334.95184.20826.57155.25934.57235.6055	66TIM
1998.93203.92883.75834.25384.99354.8968	67TIM
2113.61863.35953.33005.57646.42357.1830	68TIM
2242.53652.34472.55307.82432.92752.5662	69TIM
1964.13203.29873.31173.56373.87022.9743	70TIM
1933.70183.35223.56723.02522.63082.8555	71TIM
2073.46233.21353.49274.82734.92534.7008	72TIM
2152.42732.22432.13482.12752.23072.0450	73TIM
2143.20750.39523.67824.12104.27085.7497	74TIM
1802.22671.75482.03422.26651.68632.1217	75TIM

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2053.35532.27433.63563.41533.47553.5353                        76TIM
1803.07422.89672.84732.52252.47822.7455                        77TIM
1982.58722.50522.84972.45352.09503.0463                        78TIM
1912.94803.17103.31882.96782.55122.6998                        79TIM
2092.94552.44782.97032.52172.34622.7667                        80TIM
COL 75-76 IDENTIFIES SUBJECT NO. AND COL 77-79 IDENTIFIES TYPE OF SCORE (TIME)
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